The Adolescents' Diet from a Public Health Perspective

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“Diet is a chronic source of both frustration and excitement to epidemiologists”
Doll & Peto, 1981

“Public health medicine should refuse to accept that disease treatment means health, should reclaim ‘health’ in its original, positive and proper meaning, and subsume clinical medicine.”
Cannon G, 2003

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To Paula, Geeraard & Rita

ABBREVIATIONS

AF	Assessment Factor
BMI	Body Mass Index
BMR	Basal Metabolic Rate
bw	body weight
CVD	Cardio Vascular Disease
CSF	Cancer Slope Factor
DALYs	Disability-Adjusted Life Years
DI*i*	Daily Intake of subject *i*
EE	Energy Expenditure
EFCOSUM	European Food Consumption Survey Method
EI	Energy Intake
EU	European Union
E%	Energy Percentage
FAO	Food and Agriculture Organisation
FBDG	Food-based Dietary Guidelines
HDL	High-Density Lipoprotein
HELENA	Healthy Lifestyle in Europe by Nutrition in Adolescence
IARC	International Agency for Research on Cancer
ILSI	International Life Sciences Institute
IOTF	International Obesity Task Force
JIFSAN/NCFST	Joint Institute for Food Safety and Applied Nutrition/ National Center for Food Safety and Technology
LC-MS-MS	Liquid Chromatography-Mass Spectrometry-Mass Spectrometry
LDL	Low-Density Lipoprotein
LMS	Linearised Multistage Model
MUFA	Mono-Unsaturated Fatty Acids
NOAEL	No Observed Adverse Effect Level
NOEL	No Observed Effect Level
PUFA	Poly-Unsaturated Fatty Acids
PHN	Public Health Nutrition
RfD	Reference Dose
SE	Standard Error
SD	Standard Deviation
SDS	Standard Deviation Scores
SFA	Saturated Fatty Acids
SNFA	Swedish National Food Administration
UNFPA	United Nations Population Fund
UNICEF	United Nations Children's Fund
US FDA	United States Food and Drug Administration
USDA	United States Department of Agriculture
US-EPA	United States Environmental Protection Agency
WHO	World Health Organization

Contents

1

General Introduction

An adolescent is a person in the age of adolescence. Adolescence is the process or condition of growing up; the growing age of human beings; the period which extends from childhood to manhood or womanhood (Soanes & Stevenson, 2005). The World Health Organisation (WHO) defines an adolescent as a person between 10 and 19 years of age. One in every five people in the world is an adolescent or 1.2 billion adolescents worldwide (World Health Organization, 1997). In Belgium, adolescents represent almost 12% of the total population (Algemene Directie Statistiek en Economische Informatie, 2004).

Adolescents – no longer children, not yet adults – undergo notable physical, cognitive, social, and emotional changes in a relatively short period of time (Havighurst, 1972; Perry, 2000). In the first year of life human beings undergo a rapid growth; a second period of comparable growth is during adolescence. This phenomenon increases the body's demand for energy and nutrients. Total nutritional needs are higher during adolescence than at any other time in the life cycle. During this period, adolescents achieve the final 15-20% of their height, gain 50% of their adult body weight, and accumulate up to 45% of their skeletal mass (Gong & Heald, 1994). The nutritional needs of the adolescent population vary a lot because the sequence of physiological changes begins at different times in different individuals. On average, females have their growth spurt before males and are, for about two years, heavier and more muscular. For females, most physical growth has been completed by about two years after menarche. Males typically experience their major growth spurt and increase in muscle mass during middle adolescence (Story *et al*, 2002a). By age 20, females have about twice as much fat as males but only 2/3 as much lean body mass (Tanner, 1981).

Nutrition and physical growth are integrally related. An inadequate diet at this time can slow down or delay sexual maturation, slow down or arrest linear growth, compromise achievement of peak bone mass and also seed for diseases later in life (cfr. infra). An adequate energy intake with sufficient high quality protein is essential for optimal growth during puberty. The iron and calcium requirements are of particular concern for female adolescents who tend to limit their intake of protein-rich foods, especially dairy products (Centers for Disease Control and Prevention, 1999). It is important to note that the rate of growth is influenced by multiple factors beyond nutrition including genetics, physical activity, age, gender, and endocrine balance (Woteki & Filer, 1995).

This central period of growth and development offers special opportunities to work with adolescents and their families to help encourage healthy lifestyles.

The need for nutritional surveillance in adolescents

Historical dimension

In 1983, one of the conclusions of a Belgian symposium on "Food and Nutrition Policy in Belgium" was that not the quality of the food chain is a concern but the quantity that is consumed by school-aged children and adolescents. At this symposium it was announced that health promotion and education about nutrition have to start at young age, therefore up to date information is necessary (Verdonk, 1984).

In 1985 the topic of the World Health Day, organised by the World Health Organisation, was "Healthy youth – our best resource".

In November 1995, the WHO, along with its partners, United Nations Children's Fund (UNICEF) and United Nations Population Fund (UNFPA), advocated an accelerated approach to promote the health and development of young people in the second decade of life (World Health Organization, 1997).

According to the 'Action for Adolescent Health' report, adolescence represents a window of opportunities to prepare for a healthy adult life. During adolescence, nutritional problems originating earlier in life can potentially be corrected, in addition to addressing current ones. It is also a period to shape and consolidate healthy eating and lifestyle behaviours, thereby preventing or postponing the onset of nutrition-related chronic diseases (e.g., cardiovascular disease, cancer and osteoporosis) in adulthood (World Health Organization, 1997).

Therefore this WHO 'Action for Adolescent Health' report launched a scope of actions on different levels (World Health Organization, 1997). On the **global** level one of the themes was *"Measure"*, which means develop appropriate indicators and approaches for their measurement, for use in planning, monitoring and evaluating programmes in countries.

On the **regional** level the action *"Understand and evaluate"* was launched. This action included collecting and analysing information on the health status of adolescents and country

efforts in programming for adolescents' health. Support operations research of programming to distil best practices.
One of the actions on **country** level also is *"Understand and evaluate"*. This includes, supporting the monitoring, evaluation and operations research of programmes, including the use of appropriate indicators, putting this information to use to inform the community and improve the quality and coverage of programmes (World Health Organization, 1997).

In a more recent report the WHO European strategy for child and adolescent health and development defines health as a life-course issue and an investment in the early stages of child and adolescent health and development reaps dividends in later life and benefits the entire population (World Health Organization, 2005).

The above mentioned reports show that since decades scientists and policy-makers are aware of the importance of investing and monitoring the dietary pattern and/or the nutritional status of adolescents. The importance of nutrition in a public health context has been documented in different EU-documents. According to a European scientific review, unbalanced eating patterns and inactive lifestyles are held responsible for 30 to 40% of all cancers, at least one third of premature deaths resulting from cardiovascular diseases and the steep increase in osteoporosis and its health consequences (EURODIET group, 2001a; EURODIET group, 2001b). In a recent document it is stated that, according to an analysis made by the Swedish Institute of Public Health, in the EU, 4.5% of disability-adjusted life years (DALYs) are lost due to poor nutrition, with an additional 3.7% and 1.4% due to obesity and physical inactivity – a total of 9.6%, compared with 9% due to smoking (European Commission, 2005).

Dietary factors as determinants of disease

Different nutritional issues could be considered when one would like to see the effect of the adolescents' current diet on the risk of developing chronic diseases during adulthood. Adolescence is a period of increased nutritional needs. This period of increased energy need could lead to weight gain, which is a result of consuming more energy than is expended. Based on USA nutrition surveillance data this could be explained by a moderate increase in average calorie consumption for youth between 1980 and 1991 and a decrease in physical activity (McDowell *et al*, 1994). Belgian cross-sectional and longitudinal data indicate an increase in the degree of childhood overweight and obesity between 1969 and 1996. The prevalence of overweight is not only increasing, but the heaviest children are even heavier than before. Moreover, the risk of an overweight male adolescent becoming an overweight adult is substantial (odds ratios 5.0–6.9) (Hulens *et al*, 2001). Overweight and obesity have immediate psychological consequences, especially related to self-esteem and body image (Gortmaker *et al*, 1993). In addition a high BMI in adolescence is related to increased risk for hypertension, type 2 diabetes, cardiovascular diseases (CVD) and cancer (International Agency for Research on Cancer, 2002; Srinivasan *et al*, 1996). Along with the increase in obesity in children and adolescents a rise over the last two decades in the prevalence of type 2 diabetes in children and adolescents is found (Pinhas-Hamiel & Zeitler, 2005). The adverse effect of obesity on glucose metabolism is evident in early childhood. Obese children are hyperinsulinemic and have 40% lower insulin-stimulated glucose metabolism compared with non-obese children. Moreover, the amount of visceral fat in obese adolescents is directly correlated with basal and glucose-stimulated hyperinsulinemia and inversely correlated with insulin sensitivity (American Diabetes Association, 2000).

The consequences of type 2 diabetes during childhood and adolescence are substantial. Short term effects include limitations in usual activities, school absenteeism and an increase in hospitalizations and contact with health providers. Long term effects include increased morbidity and mortality from CVD, retinopathy, neuropathy and nephropathy. Moreover, an early age of disease onset will result in an earlier onset of disease complications (Fagot-Campagna *et al*, 2000). The increase in obesity and type 2 diabetes are short-term negative consequences of unhealthy way of life, especially diet and physical activity, during adolescence. Unhealthy dietary patterns in Belgian adolescents were already described in the early eighties (Verdonk *et al*, 1982).

Ecological and observational surveys have found a relationship between the dietary intake of saturated fatty acids, cholesterol and polyunsaturated fatty acids and an adverse blood lipid profile, an important determinant of atherosclerosis (Labarthe, 1998; Willett, 1998). There exists a convincing reduced risk for cardiovascular diseases, still the major cause of morbidity and mortality in Belgium (Nationaal Instituut voor Statistiek, 2000), when diets rich in fruits and vegetables are consumed (World Health Organization, 2003).

According to the same WHO report, overweight and obesity increase the risk for cancer of the oesophagus, the colorectum, the breast, the endometrium and the kidney. While the consumption of fruit and vegetables has a probable reducing risk-character for cancer of the oral cavity, the oesophagus, the stomach and the colorectum.

Diet appears to have only a moderate relationship to osteoporosis, but calcium and vitamin D are both important. Calcium is one of the main bone-forming minerals and an appropriate supply to bone tissue and is essential at all stages of life (World Health Organization, 2003). Peak bone mass, which is attained by the third decade of life (Heaney *et al*, 2000; Recker *et al*, 1992), is an important determinant of osteoporosis risk. Physiologically, bone mineral increases rapidly through adolescence (Bachrach, 2001; Bailey *et al*, 2000; Martin *et al*, 1997). Thus, it seems biologically plausible that the skeleton is most responsive to dietary calcium during adolescence, when bone mineral is being accrued most rapidly. So, it is shown that that early adolescent lifestyle has important effects on bone health (Wang *et al*, 2003).

On the long run, the occurrence of unhealthy dietary patterns during adolescence combined with the knowledge that eating habits developed early in life, will persist or track into adulthood (Kelder *et al*, 1994; Lien *et al*, 2001b) leads to the finding that the affluent diet is the most frequently occurring chronic disease risk behaviour in adolescents (Berenson *et al*, 1998; Lowry *et al*, 1996).

Other nutritional issues that occur in adolescents are weight-related eating disorders (Neumark-Sztainer & Moe, 2000) and meal-skipping. Meal skipping is common among adolescents, especially during middle and late adolescence. Breakfast is the most common skipped meal and is attributed to lack of time, desire to sleep longer in the morning, lack of appetite, and dieting to lose weight. Skipping breakfast may affect concentration, learning, and school performance (Centers for Disease Control and Prevention, 1996).

The WHO summarised and concluded in the 'Diet, Nutrition and Prevention of Chronic Diseases' report that there are three critical aspects of adolescence that have an impact on chronic diseases:

(i) the development of risk factors during this period

(ii) the tracking of risk factors throughout life

(iii) the development of healthy or unhealthy habits that tend to stay throughout life, for example physical inactivity because of television watching. In older children and adolescents, habitual alcohol and tobacco use contribute to raised blood pressure and the development of other risk factors in early life, most of which track into adulthood (World Health Organization, 2003).

Environmental factors as determinants of diet

It is well-known that the diet of adolescents has an impact on their overall health, on both, a short-term period and long-term period. These dietary patterns and behaviours are influenced by different factors, including peer preferences, parental modelling, food availability, food preferences, cost, convenience, personal and cultural beliefs, mass media and body image (Story *et al*, 2002b). Little of human food choice and intake on a daily basis is directly determined by the chemical composition of foods and biological characteristics of the individual. Instead, much of the observed behaviour reflects outcomes of learned cues, perceptions and responses which have been acquired through previous direct or indirect experience. Many of the interactions of food composition with its biological and social contexts lead to the expression of a relatively stable and potentially predictable set of food choice and intake behaviours (Mela, 1999).

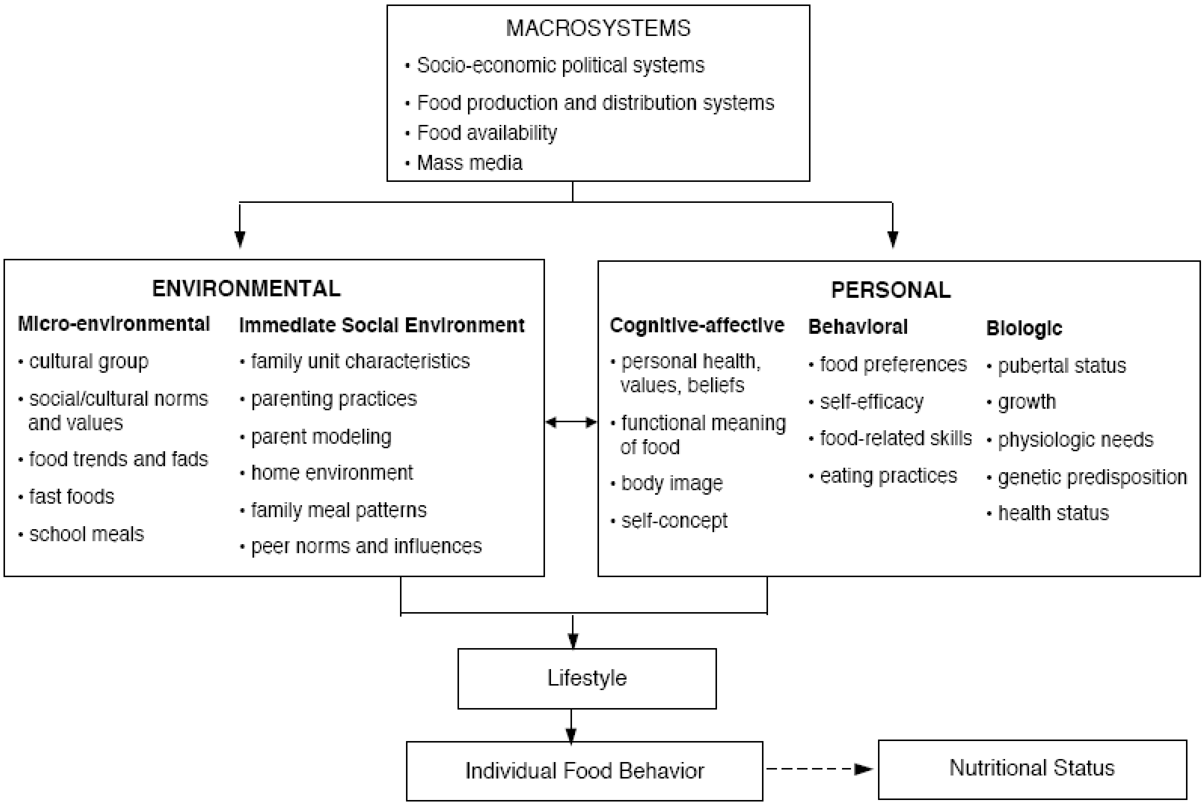
In 1998, the symposium on 'Functionality of nutrients and behaviour' Mela (1999) concluded that at the broadest level, the agro-economic and cultural background and environment shape human food choice and intake by influencing the range and quantities of foods available to human populations. These factors have also been incorporated into general cultural rules for cooking and appropriate eating behaviour, which strongly dictate much of which foods and food combinations will be eaten, when, how, and by whom. They also generate individual and group variation in opportunities and likelihood for biological predispositions and learning mechanisms to manifest themselves in certain ways (Mela, 1999).

Birch (1999) described that our genetic predispositions include the preference for sweet and salty tastes, the tendency to reject new foods, and food preferences based on the postingestive consequences and social contexts of eating. Food preferences are learned via our experience with food and eating. This emphasizes the critical role played by the food environment in determining the adequacy of diets. An infant's experience with flavours begins in utero, and during the period of exclusive milk feeding, when flavours from the mother's diet are transmitted to her amniotic fluid and later to her milk. Depending on the foods that are made available and accessible, children's learned food preferences can either promote or impede the consumption of nutritionally adequate diets. Our genetic predispositions bias us to like sweet and salty foods, humans do not have to learn to like these tastes; humans are predisposed to learn to prefer energy-dense foods over those more energy dilute; and new foods, especially those that are not sweet or salty, will be initially rejected as a result of neophobia. Fortunately, if given the opportunity, one can learn to like many of the foods that are initially rejected. This analysis suggests why “healthy” foods such as complex carbohydrates and vegetables, are initially rejected by children (Birch, 1999).

Research has demonstrated that children’s eating patterns are strongly influenced by characteristics of both the physical and social environment. With regard to physical environment, children are more likely to eat foods that are available and easily accessible, and they tend to eat greater quantities when larger portions are provided. Mealtime structure seems to be an important factor related to children’s eating patterns. It includes social and physical characteristics of mealtimes including whether families eat together, TV-viewing during meals, and the source of foods (e.g., restaurants, schools) (Patrick & Nicklas, 2005).

Story *et al* (1996) developed a conceptual model of multiple factors that influence eating behaviours of adolescents. The model depicts three interacting levels of influence which impact adolescent eating behaviours: personal or individual, environmental, and macrosystems. Personal factors that influence eating behaviour include attitudes, beliefs, food preferences, self-efficacy and also biological changes. Environmental factors include the immediate social environment such as family, friends and peer networks, and other factors such as school, fast food outlets and social and cultural norms. Macrosystem factors, which include food availability, food production and distribution systems, and mass media and advertising, play a more distant and indirect role in determining food behaviours and can play a powerful influence on eating behaviours (Story & Alton, 1996). The model is presented in Figure 1.1.

In the context of the increasing prevalence of obesity in children and adolescents, Lobstein *et al* (2004) developed a scheme with opportunities to influence a child’s environment. The newly developed scheme is similar to the model proposed by Story *et al*, and could be seen as a translation of observation into opportunity. The authors mention that preventative activities cover a broad spectrum from individual and local group-based initiatives through organisational, national and international policies (Lobstein *et al*, 2004). This is visualised in Figure 1.2.



Source: ©Mary Story. Reprinted from Story M, Alton I. Becoming a woman: nutrition in adolescence. In: Krummel DA, Kris-Etherton PM, eds. Nutrition in women's health. Gaithersburg, MD: Aspen Publishers;1996.

Figure 1.1: Conceptual model for factors influencing eating behaviour of adolescents

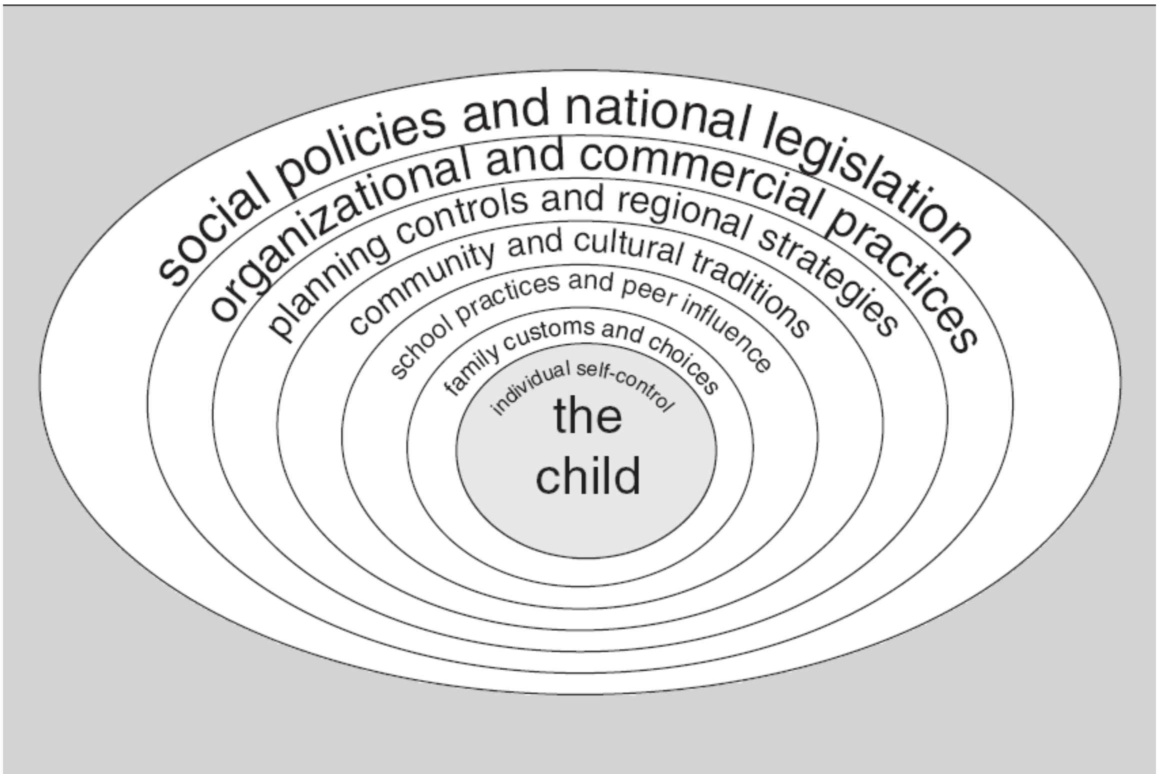


Figure 1.2: Opportunities for influencing a child's environment. (Source: Lobstein *et al*, 2004)

State of the art

To my knowledge it dates from 1978-1979 that a large nutritional survey in adolescents in Flanders – Flemish part of Belgium – was conducted (Verdonk *et al*, 1982). Since the 1978-'79 survey it is likely that the diets of young people, with the diets of adults, have changed in response for example to changes in other lifestyles, and to the variety of foods available. 'Fast food' outlets have become widely available and are popular with adolescents. In schools the type and range of foods offered has changed. In the light of these changes, the nutritional issues concerning adolescents and the actions launched by the WHO, one could conclude that there is a need for regularly updated information about the diet of adolescents. Dietary habits change over time and it is important to be aware not only of the current differences but also of any subsequent change in the future. The availability of reliable survey data also is important to ensure that estimates of dietary exposure to food chemicals are as close to reality as possible. For these reasons nutritional surveillance of this age group is needed. An opportunity to study some nutritional and food safety aspects of the current adolescents' diet was given in the context of a large multi-centre nutritional survey, namely the Ghent Adolescent Study On Nutrition (cfr. infra).

Policies and Public Health Nutrition - Cycle

Nutrition and Food Safety

This thesis – dealing with both nutritional and food safety aspects – fits in the scope of existing international political commitments. Agenda 21 (1992), a United Nations initiative, focussed on the principle that unsustainable patterns of production and consumption should be reduced (United Nations, 1992). HEALTH21 (1998), the health policy framework for the European Region highlights the importance of addressing the determinants of health, such as food and nutrition (World Health Organization, 1999). A lot of other political commitments were made the last decades and all of them stress the need for comprehensive, intersectoral policies which promote public health. In this context the First Action Plan for Food and Nutrition Policy of the World Health Organisation - European Region has been developed. This document states that a comprehensive food and nutrition policy comprises three strategies: on nutrition, food safety and a sustainable food supply, based on the principles of HEALTH21 and Agenda 21 (World Health Organization, 2001). The three strategies are interconnected, since the food supply influences both the safety and composition of food. Collaboration between the three parts is required in order to develop comprehensive, intersectoral policies and concerted action. This collaboration is schematically presented in Figure 1.3.

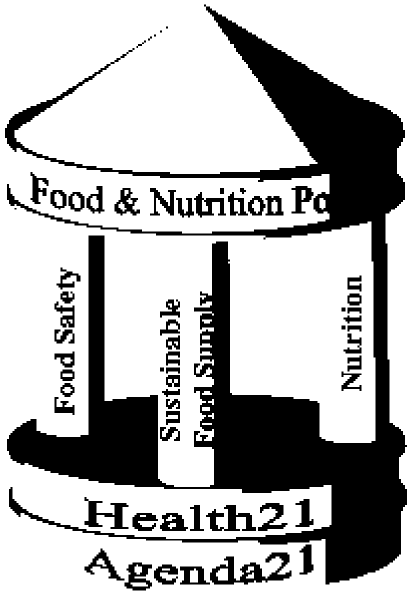


Figure 1.3: A comprehensive policy contains nutrition, food safety and sustainable food supply strategies (Source: First Action Plan for Food and Nutrition Policy – WHO Regional Office for Europe, 2001).

The three related strategies can be described as followed (World Health Organization, 2001):

- Food safety strategy: highlighting the need to prevent contamination, both chemical and biological, at all stages of the food chain. The potential impact of unsafe food on human health is causing increasing public concern and a loss of consumer confidence. The EU and WHO, both, recognize that food safety is a policy and public health priority (European Commission, 2000; World Health Organization, 2002b).
- Nutrition strategy geared to ensure optimal health, especially in low-income groups and during critical periods throughout life. Nutritional challenges vary as human's progress in the life cycle, as presented in Figure 1.4. In adolescence, many of them – especially in low-income groups – choose relatively cheap sources of energy, such as large amounts of fat and sugar, potentially leading to micronutrient deficiency, obesity and dental caries (Roos & Prattala, 1999).
- Sustainable food supply strategy to ensure enough food of good quality, while helping to stimulate rural economies and to promote the social and environmental aspects of

sustainable development. However, this topic will not be discussed in the present work.

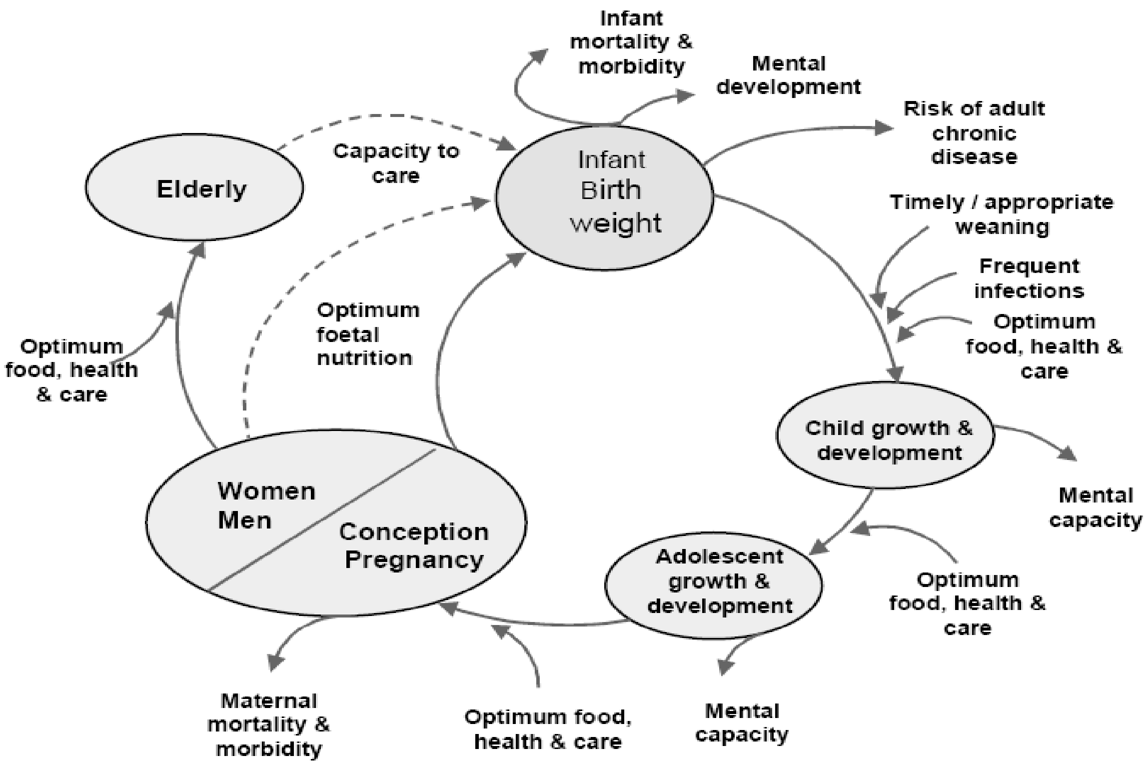


Figure 1.4: Lifecycle: the proposed causal links (Source: First Action Plan for Food and Nutrition Policy – WHO Regional Office for Europe, 2001 & adapted from Commision on the Nutrition Challenges of the 21st Century (2000) Final Report tot the ACC/SCN)

Public Health Nutrition

Public Health Nutrition focuses on the promotion of good health through nutrition and the primary prevention of diet-related illness in the population. The emphasis is on the maintenance of wellness in the whole population (Landman *et al*, 1998). Public Health Nutrition is built on a foundation of basic and applied sciences, operates in a public health context, and uses skills and knowledge of epidemiology and health promotion (Margetts, 2004).

Cannon (2003) describes that PHN seems to be a branch of nutrition science concerned with populations not individuals, prevention not treatment and humans not the rest of the living world (Cannon, 2003). In an editorial in *Public Health Nutrition* Hughes describes that this branch of science as a field of practice is rarely uncomplicated (Hughes, 2004). Caraher and Coveney (2004) argue that PHN until now has been limited to the relation between food and health rather than including consideration of the upstream components of the food and nutrition system such as food production, processing and related policy. They argue that there is a need to include food policy as a focus of analysis and intervention (Caraher & Coveney, 2004). During the last decades there were different definitions of PHN (Hughes, 2003). In 2003, an attempt was undertaken in order to assess the level of agreement regarding key descriptors used to define the field of PHN. Public Health Nutrition is still in development but is not restricted to a recent development for the healthy workforce dealing with nutrition problems. Population-based approaches have been the mainstay of nutrition work for decades in many countries (Hughes, 2003).

Recently, an evidence-based approach to PHN has been developed. The aim was to highlight the importance of an evidence-based approach to the development, implementation and evaluation of policies aimed at improving nutrition-related health in the population (Margetts *et al*, 2001). As Public Health Nutrition is about solving problems, a PHN cycle has been designed to identify the key steps required to develop a logical approach to the best way to solve problems (Margetts, 2004). This PHN cycle is presented in figure 1.5.

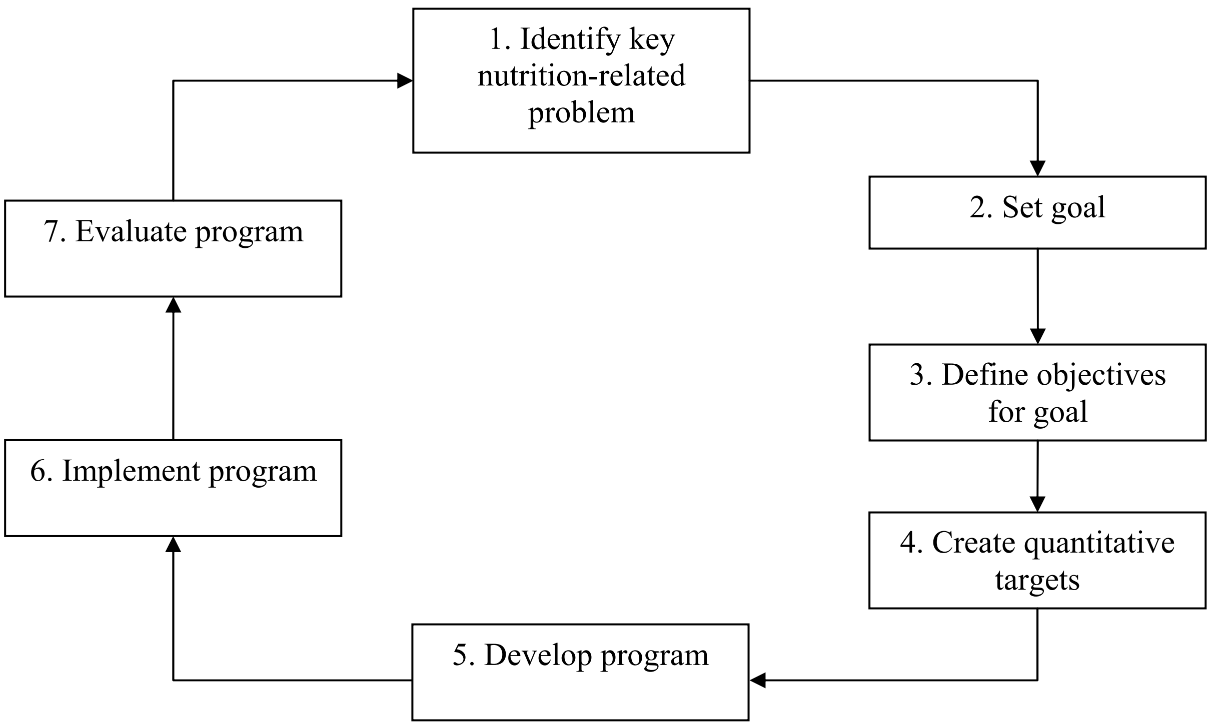


Figure 1.5: Public Health Nutrition Cycle (Margetts, 2004)

History of adolescent nutritional surveys in Belgium

The WHO launched in their 'Action for adolescent health'-report and other reports that measuring of appropriate indicators for monitoring purposes is needed and there is a need of regularly updated information about the diet of adolescents (World Health Organization, 1997). However, a limited number of surveys on dietary habits of adolescents have been conducted in Belgium.

The oldest survey that the author could find was conducted in 1978-1979 in school-aged children and adolescents in Flanders, in the region of Wetteren (Verdonk *et al*, 1982). A total of 598 adolescents (13 – 19 years) completed one 24h dietary recall. According to the research group, adolescents had a high soft-drink (361 ml/day) and beer (125 ml/day) consumption and a low consumption of vegetables (115 g/day), potatoes (271 g/day) and milk (338 ml/day). On nutrient level the intake of total carbohydrates was low compared to the recommendations (49.2 E% vs. 50-60 E%), while the intake of total fat was high (37.2 E% vs. 30-35 E%). The intake of protein was within the range of the recommendations (12.3 E% vs. 10-15 E%). More specific saturated fat intake and mono- and disaccharides represented a huge proportion of the total energy intake.

In 1990, Flanders participated for the first time in the Health Behaviour in School-aged Children (HBSC)-study. The overall aim of the study was/is to monitor and to increase the understanding of lifestyle behaviours of young people. A restricted food frequency questionnaire concerning meal patterns and the consumption of items such as fruit, vegetables, sweets and soft drinks was used. The obtained data gave information about the frequency of consumption of different food items (Vereecken *et al*, 2005b).

More recently (1996), a survey among vegetarian adolescents has been conducted. The focus of the study was on growth, development and physical fitness. Dietary data was obtained by using a self-administered seven day food frequency questionnaire. A sample of 16 (6 boys and 10 girls) was collected. Energy intake was considerably lower than the mean reference data. The mean energy intake for boys was 1915 kcal and for girls 1403 kcal (Hebbelinck *et al*, 1999).

In the French part of Belgium the Adolux-study (1995) is the most detailed survey in the field of nutritional epidemiology. The purpose of the survey was to analyse the usual dietary habits of Belgian adolescents from a high cardiovascular risk population. The survey was conducted in the Belgian province of Luxembourg. A food frequency questionnaire (57 items) was administered to the whole sample. Complementary questions specified some types of food (e.g., fat content). A total of 1526 adolescents (12 ± 17 y) selected by a multistage cluster sampling, participated in the study (participation: 83.6%). Respectively 46% and 60% of the adolescents did not eat fruit and vegetables daily. Most of the adolescents (72%) consumed at least one dairy product daily. The frequent consumption of chocolate and French fries indicated the strong cultural influence on dietary habits while imported foods (like hamburgers) had little success. Boys and girls differed significantly in their diet, with girls choosing healthier foods. Dietary habits, in particular drinking habits, differed also significantly between education levels, assessed by the learning option of the participants. The semi-quantitative questionnaire showed that two-thirds of the adolescents had a lipid intake (mainly saturated fatty acids) which exceeded 35% of the total caloric intake. Polysaccharides represented less than half of the total carbohydrates intake. The study of the diet of Belgian adolescents confirmed the strong influence of tradition, in particular on the consumption of high fat content foods (Paulus *et al*, 2001).

Another study conducted in the French speaking part of Belgium has been conducted in 1997 and 2001 by the ‘Observatoire de la Santé du Hainaut’. A restricted questionnaire was used to collect data. Information about the consumption of fruit, vegetables and French fries has been collected. On average 1/3 of the 16-years adolescents did not consume breakfast, almost 60% did not consume every day fruit and 40% did not consume daily vegetables (Observatoire de la Santé du Hainaut, 1998; Observatoire de la Santé du Hainaut, 2001).

The Ghent Adolescent Study On Nutrition (GAStON) (conducted between March 1997 and May 1997) is the only adolescent nutritional survey in Belgium that collected information over a period of seven consecutive days and is the most recent survey that reflects reliable detailed information about nutrient and food intake in adolescents.

Objective of the thesis

The First Action Plan for Food and Nutrition Policy of the WHO proposed two actions:

(i) monitoring health information

(ii) improving knowledge.

The monitoring health information approach asks for comprehensive systems for monitoring food and nutrient intake, nutritional status and the incidence of foodborne diseases. Foodborne illness can be caused by microbiological, chemical or physical hazards. According to the improving knowledge approach there is need of providing scientific evidence of positive or negative impact of food and food habits on health. There is a need to gather, assess and disseminate existing knowledge, and to identify areas where the links require clarification and further research. This in line with two European Union projects (EU DG Health and Consumer Protection, 2003; Steingrimsdottir *et al*, 2002).

Therefore the present thesis could be seen as a cross-sectional baseline project in the field of Public Health Nutrition (PHN) focussing on different aspects of the First Action Plan for Food and Nutrition Policy, namely nutritional challenges in adolescents with a specific emphasis on social inequalities and an illustration of food safety challenges.

The overall objective of this thesis is to study the dietary pattern of a population of Flemish adolescents and its health consequences on the adolescents' current and later life, in both dimensions food safety and nutrition. More specifically, the following aims can be put forward:

(i) to study meal patterns, food and nutrient intake

(ii) to study associations between food and nutrients

(iii) to study the impact of social quantification on food habits

(iv) to explore the food safety dimension on the basis of a chemical substance, more precisely acrylamide. This substance has been chosen because it was at that time of high concern in the EU (European Commission, 2002a).

(v) to study some methodological issues in nutritional epidemiological research

The objective will be tackled on the basis of a population based random sample of adolescents (cfr. Infra).

Ghent Adolescent Study On Nutrition (GAStON)

Material & Methods

The Ghent Adolescent Study On Nutrition was part of an international collaborative project, including Ireland, Finland, Germany, Italy and Belgium, looking at methodological aspects of dietary assessment in the context of food safety monitoring. The international project investigated the influence of survey duration on food intake estimates and the comparison of a combined 3-day food diary and food frequency questionnaire with a 14-day food diary for estimating mean food intakes among consumers only (Lambe *et al*, 2000a).

For Belgium, the purpose was not only to collect data in the context of food safety monitoring but also to analyse the data in more depth in order to allow for a cross-sectional description of the dietary habits in this subgroup of the population (boys and girls aged 13 – 18 years).

The study was carried out between March and May 1997. The target population was defined as adolescents attending schools in the city of Ghent - a medium sized (N = ± 225000) city in Flanders, the northern Dutch-speaking part of Belgium. A random sample of 13 – 18 years old adolescents was drawn on the basis of a multistage cluster sampling technique.

In a first step, local schools from both the private and public school-network were randomly selected. All contacted schools (N=5) agreed to participate. In a second step, different educational options were represented in the sample. In Belgium, students can essentially choose between a so-called “general” education (mainly theoretical courses) or “vocational” training (in which 25 to 75 % of the time is focussed on practical skills). Finally, classes were randomly selected as final cluster units. Selection of classes was aimed at establishing a distribution of teenagers over the full age range in both sexes. All students from the selected classes were considered eligible for the study.

The described sampling procedure yielded a sample of 656 students, who were officially registered in the 48 sampled classes. Non-eligible students (N= 91) were either on sickness leaves or had moved to other schools, so eventually only 565 students were considered eligible. Of these, 411 individuals (72.7%) actually participated. The food diaries of 70 students had to be excluded from analysis. Most of the rejected food diaries were excluded on the basis of incompletely recorded days. Others had very unrealistic data which could not be corrected in a reliable way. The standardisation of the exclusion procedure was guaranteed by the fact that the evaluation of the food diaries was done by the same dieticians, who have a long standing experience in nutritional epidemiologic fieldwork. Hence, results are reported for 341 students. Considering the number of students that were originally invited, the number of full seven day records represents 60.3% participation. In Figure 1.6 the sampling procedure and selection of participants is presented.

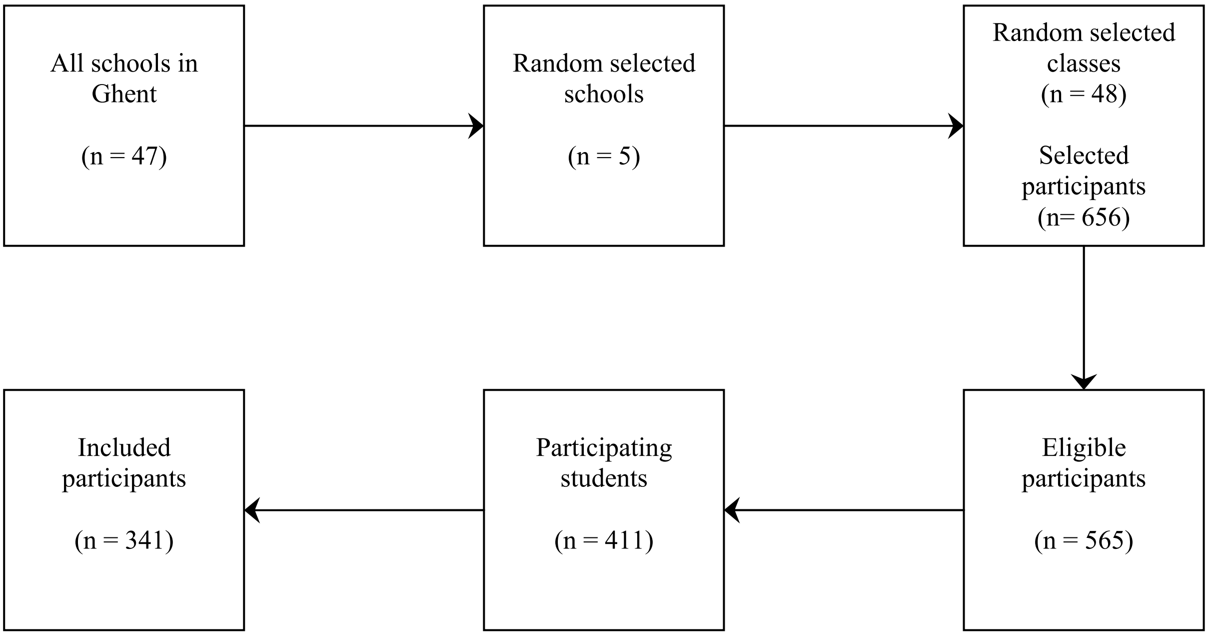


Figure 1.6: The selection procedure of participants

The dietary assessment method used in the GAStON project was a seven day estimated food record method, using a semi-structured diary. The 14-day food diary was only used in the broader international project. In the diaries, days were truncated into six eating occasions, namely breakfast, lunch, dinner and snacks (divided in morning, afternoon and late-evening snacks). Breakfast can be defined as the first meal in the morning. Lunch and dinner can either be cold or hot meals; lunch is a meal in the middle of the day before 3 p.m. and dinner is served after 3 p.m. The snacks refer to a summation of the morning, afternoon and late-evening snacks. Information on the type (including brand names) and amount of food consumed was collected through an open entry format. For each eating occasion, the time of consumption was recorded. For each day, specific information on the type of fat used for cooking and frying was collected on a separate sheet, along with recipes for homemade dishes.

Methodological issues

The appropriate tool for dietary assessment depends on the purpose for which it is needed. The purpose in the GAStON-project was to measure nutrients, foods and eating habits. Food diaries are written reports of foods eaten during a specified length of time. This involves an individual estimating each and every item of food and drink prior to consumption. A food-intake record, lasting for several days (3 to 7 days), provides a more reliable estimate of an individual's nutrient intake than do single-day records (Cameron & van Staveren, 1988; Thompson & Byers, 1994). Records kept for more than 3 days increase the likelihood of inaccurate reporting because an individual's motivation has been shown to decrease with increasing number of days of dietary data collection, especially if the days are consecutive (Buzzard, 1998; Gersovitz *et al*, 1978). On the other hand, records maintained for shorter times may not provide accurate data on usual food and nutrient intakes. The actual number of days chosen to collect food records should depend on the degree of accuracy needed, the day-to-day variability in the intake of the nutrient being measured, and the cooperation of the subjects. The number of days of records required to rank individuals depends on within-subject:between-subject variance (variance ratio) in nutrient/food intake: the larger the ratio, the more days of recording are required to rank individuals correctly. The few studies that have examined this issue in children and adolescents have clearly demonstrated that the variance ratios for children's nutrient intakes are much greater than are those for adults (Farris *et al*, 1985a; Farris *et al*, 1985b; Miller *et al*, 1991; Nelson *et al*, 1989; Palaniappan *et al*, 2003). Livingstone and co-workers (2004) describe that the variance ratios for adolescents are approximately twice those observed in adults. Higher variance ratios for nutrient intakes in these groups have a number of important implications for the design and interpretation of dietary surveys. The major issues that Livingstone and co-workers raised were: firstly, the finding that prolonged recording may be required to characterize the intakes of many nutrients has major implications for the choice of survey instrument and the design of surveys. Secondly these high variance ratios have been based, at least until recently, on the assumption that the dietary data represent valid measures of habitual food intake (Livingstone *et al*, 2004). These issues will be discussed in more detail in the final chapter. However, these issues raise considerable caution when evaluating available data.

The validity and reliability of the dietary records depend on the participant's ability to provide accurate data. Food records must be maintained carefully to maximize the accuracy of the diary. Food intake should be recorded at the time the food is eaten to minimize reliance on memory. Recording error could be minimized if instructions and proper directions on how to approximate portion sizes and servings of fluid are provided (Bingham, 1991; Cameron & van Staveren, 1988).

For risk assessment purposes, the length of time over which dietary samples are to be collected is several consecutive days at multiple intervals of months, seasons and years (Kroes *et al*, 2002). However, in exposure assessment no consensus is achieved about the time frame to be used in the assessment of intake of food chemicals (Kroes *et al*, 2002). On the other hand, it was found that the diet history method is probably the best choice, followed by dietary records, to estimate exposure to food additives (Lowik, 1996). Nevertheless, various strategies for exposure calculation can be achieved depending on the nature of the available data; this is extensively described by Kroes and co-workers (2002). To evaluate the exposure to contaminants a probabilistic assessment was conducted (Cullen & Frey, 1999). A probabilistic exposure assessment uses probability distributions for one or more variables in an exposure equation in order to quantitatively characterize variability and/or uncertainty. A Monte Carlo simulation is perhaps the most widely used probabilistic method. Monte Carlo simulation uses computer simulations to combine multiple probability distributions in exposure or risk equations. In contrast to probabilistic approach, a deterministic assessment uses point estimates for each of the variables in the exposure algorithm. The result is a single estimate of exposure. The output of a probabilistic assessment is a probability distribution of exposures that reflects the combination of the input probability distributions. If the input distributions represent variability, then the output distribution can provide information on variability in the population of concern. If the input distributions reflect uncertainty, then the output distribution can provide information about uncertainty in the estimate. The probabilistic risk assessment can be used to make statements about the likelihood of exceeding a risk level of concern, given the estimated variability in elements of the risk equation. Since the results of point estimate methods generally do not lend themselves to this level of risk characterization, the probabilistic risk assessment can provide unique and important supplemental information that can be used in making risk management decisions (Cullen & Frey, 1999; Edler *et al*, 2002; European Commission, 2003b; Gibney & van der Voet, 2003; Petersen, 2000; Petersen & Barraj, 1996; US Environmental Protection Agency, 1997).

Outline of the thesis

The cross-sectional GAStON-survey gave the opportunity to identify some key nutrition-related and food safety problems in a subgroup of the population. Chapters 2, 3 and 4 focus on the nutritional aspects of the thesis. Chapter 2 describes the estimated energy intake, macronutrient intake and meal pattern of adolescents. In chapter 3, the position of breakfast in the overall diet has been investigated in more detail and more precisely the importance of breakfast in relation to the global dietary pattern has been studied. Chapter 4 searches for the main food sources of total fat and saturated fatty acids with the purpose to develop food-based dietary guidelines for adolescents. Chapter 5 gives an overview of social inequalities at nutrient and food level between different socioeconomic groups based on the educational training of the adolescent and the educational level of the parents. Chapter 6 is an illustration of one of the many food safety aspects that can occur in the dietary pattern of adolescents. The consumption data are linked to contamination data (e.g., acrylamide) to estimate the long-term intake of contaminants. The use of a probabilistic model is preferred, in stead of a deterministic model. Chapters 2 and 7 describe some methodological issues about the accurate assessment of food and nutrient intakes in adolescents, in order to understand how methodological considerations could affect the results found in the other chapters. Chapter 7 is also future oriented. An attempt has been undertaken to define an uniform methodology that will be used in future European adolescent dietary surveys. Finally, in chapter 8, overall considerations and methodological problems are discussed and some general conclusions are drawn.

2

ESTIMATED ENERGY, MACRONUTRIENT INTAKE AND MEAL PATTERN OF FLEMISH ADOLESCENTS

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Abstract

Objective: To describe the energy and macronutrient intake and the meal patterns of Flemish adolescents, aged 13 – 18 y.
Methods: A 7 day estimated food record was administered to the whole sample.
Setting: Secondary schools in the city of Ghent, Belgium.
Subjects: A total of 341 adolescents (13 – 18 y) selected by a multistage clustered sampling (participation: 72.7%).
Main results: A significant increase with age was observed in total energy intake in adolescent boys ($P < 0.01$), but not in girls. The energy distribution over the macronutrients showed no significant difference between boys and girls. On average, 35.7% (SD 4.81%) of energy came from total fat and 15.4% (SD 2.46%) from saturated fatty acids; 49.0% (SD 5.28%) from total carbohydrates with 25.1% (SD 4.49%) from polysaccharides and 23.9% (SD 5.86%) from mono/disaccharides. The energy contribution of alcohol in the 16 – 18 y-old-group was significantly higher as compared with the 13 – 15 y-old-group, for both boys and girls. Snacks between meals accounted for almost 20% of the total energy intake. Lunch and dinner were characterized by high total fat content.
Conclusion: These students consumed a diet high in total fat and in saturated fatty acids and also high in mono- and disaccharides. Observed mean intakes deviate considerably from the Belgian dietary guidelines. A low energy intake at breakfast was observed, while a higher proportion of energy was derived from snacks.

Introduction

Adolescence is a particularly unique period in life as it is characterized by intense physical, psychosocial and cognitive development. From nutritional point of view, this transition period from childhood to adulthood deserves special attention in view of the dramatic physical changes of the body. Increased nutritional needs relate predominantly to the fact that adolescents gain up to 50% of their adult weight, more than 20% of their adult height and 50% of their adult skeletal mass during this period (World Health Organization, 1995).

Moreover, there is evidence that an unfavourable nutritional profile – in terms of foods, meals, macronutrients, micronutrients, non-nutrients, etc – during adolescence, is related to adverse health outcomes in later adult life.

The EURODIET project (a European effort to enable a coordinated EU and member state health promotion programme on nutrition, diet and healthy lifestyles) (Kafatos & Codrington, 1999) has recently summarized the potentials of healthy lifestyles, particularly diet, weight control, physical activity and non-smoking, in the prevention of chronic diseases. Diet-related lifestyles are considered to be responsible for about 10% of the so-called disability adjusted life years lost (DALYs) and therefore they also have a considerable impact on public health costs.

On the basis of this knowledge, it is clear that monitoring dietary habits in different subgroups of the general population is of great interest for public health. Until now, there has been almost no epidemiological data on nutrient intake of adolescents available in Belgium. The latest Flemish survey, based on a one day food record, dates from 1978 (Verdonk *et al*, 1982) and the latest Walloon survey, based on a food frequency questionnaire, dates from 1995 (Paulus *et al*, 2001).

The aim of the present study, therefore, was to estimate food consumption and nutrient intake in a random sample of Flemish adolescents aged 13 – 18 y. In this paper results are presented on the daily energy and macronutrient intake of teenagers and on their meal patterns; a comparison is made with other European studies and with the recommendations from the National Nutrition Council.

Materials and methods

The present study was part of an international project, including Ireland, Finland, Germany, Italy and Belgium, looking at methodological aspects of dietary assessment in the context of food safety monitoring (Lambe *et al*, 2000b). For Belgium, the data were analysed in more depth in order to allow for a cross-sectional description of the dietary habits in this subgroup of the population (boys and girls aged 13 – 18 y).

The study was carried out between March and May 1997. Subjects were residents in the region of Ghent, a medium sized (n = ± 225 000) city in Flanders, the northern Dutch-speaking part of Belgium.

A random sample of 13 – 18-y-old adolescents was drawn on the basis of a multistage cluster sampling technique. In a first step, local schools from both the private and public school-network were randomly selected. All contacted schools (n=5) agreed to participate. In a second step, a stratification according to the learning option ascertained that all social backgrounds were represented. In Belgium, students can essentially choose between a 'classical' education (mainly theoretical courses) or vocational training (in which 25 –75% of the time is focussed on practical skills). These different educational options were proportionally represented in the sample.

Finally, classes were randomly selected as final cluster units. Selection of classes was aimed at establishing a uniform distribution of teenagers over the age range 13 – 18 y in both sexes. All students from the selected classes were considered eligible for the study.

Information letters were sent to directors, parents and the adolescents, who were all asked to give their written consent. The recruitment and the fieldwork were carried out in collaboration with the local Medical School Services. These medical services have medical records of all registered students on the basis of repeated obligatory medical examinations in the schools.

The described sampling procedure yielded a sample of 656 students, who were officially registered in the 48 sampled classes. Non-eligible students (n=91) were either on sickness leave or had moved to other schools, so eventually only 565 students were considered eligible. Of these, 411 individuals (72.7%) actually participated.

Dietary assessment was done on the basis of a 7 day estimated food record method, using a semi-structured diary. Students were informed about the aim of the study and were given necessary instructions for accurate completion of the food diary. Special attention was thereby given to the issue of estimation of portion sizes of food items and this was demonstrated with a number of standardized examples.

In the diaries, days were truncated into six eating occasions, namely breakfast, lunch, dinner and snacks (divided in morning, afternoon and late-evening snacks). Information on the type (including brand names) and amount of food consumed was collected through an open entry format. For each eating occasion, the time of the day was recorded.

For each day, specific information on the type of fat used for cooking and frying was collected on a separate sheet, along with recipes for home-made dishes. Every 2 days, the diaries were checked for quality and completeness by experienced dieticians. After completion, the diaries were processed into food quantities and codes by experienced dieticians on the basis of a standard protocol, including a standard manual on food portions and household measures (Vakgroep Humane Voeding en TNO Voeding, 1997). Food codes from the Dutch Food Composition Tables (NEVO, 1993; NEVO, 1996) and from the Belgian Food Composition Table from 1992 and 1995 (NUBEL, 1992; NUBEL, 1995) were used. Calculation of nutrients was done by means of a nutritional software package developed by the Unilever company in the Netherlands (Unilever, 1992).

It was decided beforehand that only good quality food diaries with a full 7 days record would be considered. Therefore, the food diaries of 70 students had to be excluded from analysis. Most of the rejected food diaries were excluded on the basis of incompletely recorded days. Others had very unrealistic data which could not be corrected in a reliable way. The standardization of the exclusion procedure was guaranteed by the fact that the evaluation of the food diaries was done by the same dietician, who has a long-standing experience in nutritional epidemiologic fieldwork. Hence, results are reported for 341 students. Considering the number of students that were originally invited, the number of full 7 day records represents 60.3% participation.

Average energy intake and nutrient intakes were calculated as the mean of the 7 day intake period; the same procedure was followed for the estimation of the meal specific energy and macronutrient intake. Breakfast can be defined as the first meal in the morning. Lunch and dinner can either be cold or hot meals; lunch is a meal in the middle of the day before 3 pm and dinner is served after 3 pm. The snacks refer to a summation of the morning, afternoon and late-evening snacks.

Statistical analysis was done with the SPSS software (SPSS, 1999). Descriptive statistics used means and standard deviations for continuous data. Tests for normality were performed, using a Kolmogorov – Smirnov test. Student's t-tests were used to compare the means of the different groups. Chi-square test was used to compare proportions. A P-value of <0.05 was taken as threshold for significance.

In this paper, a distinction is made between 'included individuals' and 'non-included individuals', referring to, respectively, full participants and subjects who either refused or who have been excluded on the basis of quality control procedures.

Members of the research-unit measured heights and weights of all 'included' subjects. The measurements were carried out according to the standardized method as described in WHO, Technical Report Series 854 (World Health Organization, 1995). Data on measured heights and weights were completed in the same period (within 1 week) as the dietary diary. For a random sub-sample of the 'non-included' subjects – respectively 48 boys and 64 girls – heights and weights were obtained from medical records from the local School Medical Services. The body mass index (BMI) was computed as weight (kg) divided by the square of height (m^2). No standard definitions of overweight or obesity in adolescents are defined in Belgium. Instead, the internationally accepted age- and sex-specific cut-off points for body mass index related to overweight and obesity in children (using dataset specific centiles linked to adult cut-off points, developed by Cole *et al*, 2000) were used. The reference population in this method is based on six large nationally representative cross-sectional surveys on growth from Brazil, the UK, Hong Kong, the Netherlands, Singapore and the United States. Estimates of basal metabolic rate (BMR) have been derived from standard equations based on weight, age and sex (Schofield *et al*, 1985). The formulas used in this study are shown for males and females aged 10 – 18 y:

$$\text{male BMR (MJ)} = 0.0732 \times (\text{weight (kg)}) + 2.72$$

$$\text{female BMR (MJ)} = 0.0510 \times (\text{weight (kg)}) + 3.12$$

A comparison of energy intake with estimated BMR can be used to estimate the number of respondents in a dietary survey who might be under-reporting their energy intake. For individuals in a non-dieting population, it is suggested that a ratio between energy intake and BMR of less than 1.35 (cut-off 1) is unlikely to reflect habitual intake. To detect if the reported energy intake is a plausible measure of the actual diet during the measurement period, a second cut-off value (cut-off 2) was introduced. The derivation of the cut-off 2 is based on the assumption of energy balance and takes into account several parameters (Goldberg *et al*, 1991). The calculation of cut-off 2 in this study was done under the following conditions: data on an individual level; 7 days per subject; estimated values for BMR taken from Schofield equations and the lower limit of the 95% confidence interval. On the basis of these calculations, the value of the second cut-off value was 1.1. On the other hand an instrument to detect the over-reporters in a dietary survey does not exist.

The study was approved by the Ethical Committee of the Faculty of Medicine and Health Sciences of the Ghent University.

Results

The characteristics of the study population are shown in Table 2.1. In both boys and girls, the loss of subjects (due to non-participation or incomplete diary) was significantly higher in students from vocational education as compared with students from theoretical education. A similar phenomenon was observed for age with higher proportional drop-out in older age groups as compared with younger age-groups (this could however not be tested in a formal way because of missing values, cfr. Table 2.1).

Table 2.1: Characteristics of included and non-included food subjects by sex: effects of education level and age-group

	Boys		Girls		Total
	Included	Non-included	Included	Non-included	Invited
N	129	104	212	120	565
Education Type					
Theoretical (n) (%)	112 (62 %)	68 (38 %)	101 (78 %)	28 (22 %)	309
Vocational (n) (%)	17 (32 %)	36 (68 %)	111 (55 %)	92 (45 %)	256
Age-groups					
13 – 15 years (n)	74	13†	89	28†	204†
16 – 18 years (n)	55	67†	123	63†	308†

† Birthday data of 24 boys and 29 girls are missing

In Table 2.2, anthropometrical data from the study population are compared with the data from a random sub-sample of the 'non-included' subjects. In both boys and girls, weight was not significantly different between participants and non-included individuals, whereas height was significantly higher in non-included boys as compared with participating boys. The proportion of boys who suffer from overweight does not differ between the included and the non-included subjects. In girls, the difference between overweight and non-overweight subjects is almost 6%, although not significant. In Figure 2.1 the distribution of the ratio of the reported energy intake (EI) and estimated BMR and the percentage of respondents with energy intake/BMR values less than 1.35 and 1.1, respectively, are shown. The average EI/BMR ratio in boys and girls is, respectively, 1.56 and 1.36. The proportion of adolescents below cut-off 1 is 19.4% for boys and 46.7% for girls. The percentage of respondents with a EI=BMR ratio below cut-off 2 is 7.8% for male subjects and 20.3% for female subjects.

Table 2.2: Height, weight and overweight of the study population

	Boys		Girls	
	Included	Non-included	Included	Non-included
Height (in cm) (SD)	174.2 (8.9)	177.6 (7.9)¶	165.8 (6.1)	165.6 (6.5)¶
Weight (in kg) (SD)	60.7 (10.7)	63.6 (10.1)¶	59.1 (10.9)	60.7 (10.1)¶
Overweight (%)	6.2	6.3	14.4	20.3

¶ Measurements of 48 boys and 64 girls were included in the non-included sub-sample

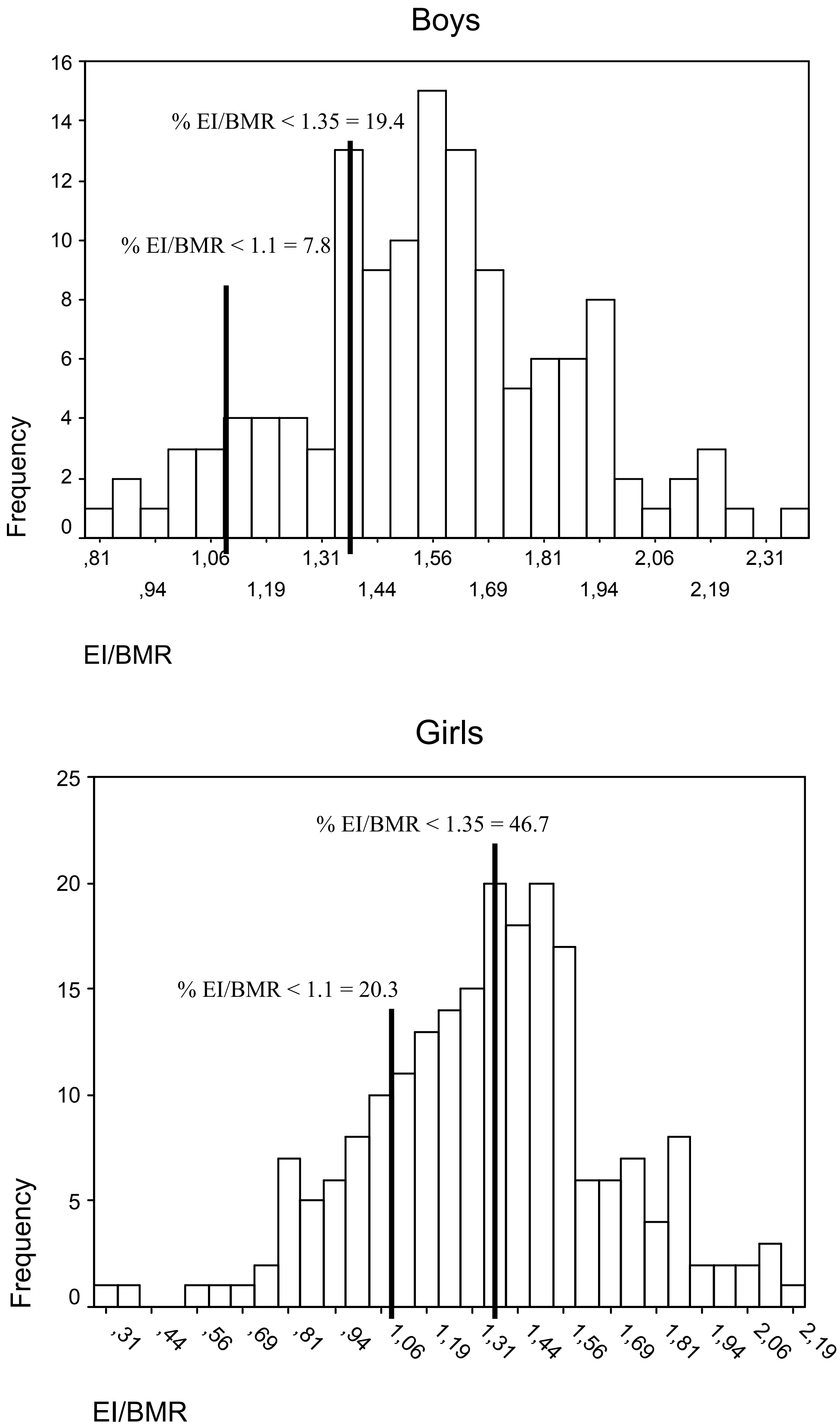

Figure 2.1: Comparison of energy intakes with estimates of basal metabolic rate (BMR)* in adolescent boys and girls

* Based on estimates by Schofield *et al*. (1985)

In Table 2.3, the mean energy intake is shown by sex and age-group. The mean energy intake in the 13 – 15-y-old group was 10.6±2.12 (SD) MJ for boys and 8.0±1.92 MJ for girls, while in the 16 – 18-y-old group, it was respectively 11.7±2.1 MJ for boys and 8.4±2.01 MJ for girls. In both age groups, the energy intake in boys was significantly higher as compared with girls ($P<0.001$). A significant increase in total energy intake over the age groups was observed in boys ($P<0.01$), while in girls no significant differences were found between the age groups. Table 2.3 also shows the mean overall energy contribution from proteins, carbohydrates, fats and their sub-fractions, and alcohol. The overall picture of energy contribution from macronutrients is very similar in boys and girls from both age groups. Protein contributed on average 14.5% to the energy intake, fat 36% and total carbohydrates 49%. Saturated fatty acids represented the largest fraction of the total ingested fat. The energy contribution of alcohol in 16 – 18-y-old group was significantly higher as compared to the 13 – 15-y-old group, although the contribution of alcohol to the total energy intake was limited. Except from alcohol, there were no statistical differences between the two sexes and the two age-groups, in relative energy contribution from any of the other macronutrients. Fibre intake is also included in Table 2.3; in absolute figures boys had a significant higher intake than girls in both age groups and the youngest boys had a significant lower fibre intake than the older ones. In relative figures (expressed as g/10 MJ), female adolescents had a higher intake than their counterparts. There was only a significant difference between boys and girls of the youngest age group.

Table 2.3: Mean energy intake (SD) (kJ), mean intakes (SD) of macronutrients (in energy %) and fibre (in g/d and g/10 MJ per day) by sex and age-group

	13 – 15 years			16 – 18 years			P-value	P-value
	Boys	Girls	P-value	Boys	Girls	P-value	Boys¶	Girls†
Energy	10625 (2120.2)	8030 (1973.8)	***	11744 (2062.4)	8400 (1813.7)	***	***	N.S.
Protein	14.7 (2.05)	15.3 (2.52)	N.S.	14.0 (1.97)	14.6 (2.66)	N.S.	N.S.	N.S.
Carbohydrates, total	49.1 (4.62)	49.1 (5.37)	N.S.	48.3 (5.45)	49.3 (5.54)	N.S.	N.S.	N.S.
Mono/disaccharides	24.3 (4.90)	24.3 (4.95)	N.S.	23.3 (6.48)	23.8 (6.69)	N.S.	N.S.	N.S.
Polysaccharides	24.8 (4.37)	24.8 (4.56)	N.S.	25.0 (4.11)	25.5 (4.69)	N.S.	N.S.	N.S.
Fat, total	36.1 (4.54)	35.5 (5.01)	N.S.	36.3 (4.57)	35.4 (4.95)	N.S.	N.S.	N.S.
SFA	15.7 (2.46)	15.4 (2.67)	N.S.	15.3 (2.53)	15.3 (2.29)	N.S.	N.S.	N.S.
MUFA	14.4 (2.25)	14.1 (2.44)	N.S.	14.8 (2.12)	14.2 (2.57)	N.S.	N.S.	N.S.
PUFA	6.1 (1.59)	5.9 (1.29)	N.S.	6.2 (1.59)	5.9 (1.57)	N.S.	N.S.	N.S.
Alcohol	0.2 (0.40)	0.2 (0.57)	N.S.	1.5 (2.52)	0.7 (1.39)	N.S.	***	***
Fibre (in g)	19.0 (5.89)	15.8 (5.22)	***	21.3 (5.73)	15.9 (5.46)	***	*	N.S.
Fibre (in g/10 MJ)	18.0 (4.83)	20.2 (6.24)	*	18.4 (5.14)	19.1 (5.43)	N.S.	N.S.	N.S.

SFA = Saturated Fatty Acids; MUFA = Monounsaturated Fatty Acids; PUFA = Polyunsaturated Fatty Acids

¶ Difference between 13 – 15 years old and 16 – 18 years old boys

† Difference between 13 – 15 years old and 16 – 18 years old girls

* Significant at the 0.05 level

*** Significant at the 0.001 level

N.S. Not Significant

In Figure 2.2 the energy contribution of macronutrients is compared to the Belgian dietary recommendations (Nationale Raad voor de Voeding, 1996). The National Nutrition Council advises a mean population protein intake of about 10% of the total energy intake. Almost all boys and girls had a higher intake than 10%. As for total carbohydrates (derived by the 'difference' method), the National Nutrition Council advises a lower limit of 55% to cover the carbohydrate requirement of adolescents. Around 20% of the adolescents had a total carbohydrate intake lower than 45% of the total energy intake. Only 10.1% of the boys and 11.8% of the girls had a relative carbohydrate contribution higher than 55%. In more detail, the recommended relative contribution of polysaccharides (combination of all polysaccharides) amounts at least 50%. Only 12.4% of the boys and 15.1% of the girls had a relative contribution higher than 30%. Concerning total fat intake, a maximum limit of 30% is recommended. More than 90% of the participants had a relative fat intake higher than 30%. About 20% of both sexes even had an intake of more than 40% of the total energy. About 79% of the boys and 72% of the girls fell within the recommended range for polyunsaturated fatty acids (PUFA) intake (3 – 7%). The saturated fatty acid (SFA) intake is recommended to be less than 10% of the total energy intake. Only 1.5% of the boys and girls met this advice. More than 50% of the boys and the girls had an SFA intake higher than 15% of the total energy intake.

In Table 2.4 data from this study are compared with results from a similar survey in Flemish adolescents (Verdonk *et al*, 1982), carried out almost 25 y ago in a region close to Ghent and with the Belgian dietary recommendations (Nationale Raad voor de Voeding, 1996). The major differences can be summarized as follows: the mean energy intake is lower today than 25 y ago; the mean relative contribution of carbohydrates has remained constant, although the mean relative intake of mono/disaccharides has increased; the mean relative contribution of proteins has increased. The decrease in mean relative saturated fatty acids intake between 1978 and 1997 was apparently compensated for by an increase in the mean relative unsaturated fatty acid intake, resulting in a steady-state situation in the total fat intake. On the whole, the energy intake and the macronutrient profile in the present study are more in accordance with the Belgian dietary guidelines.

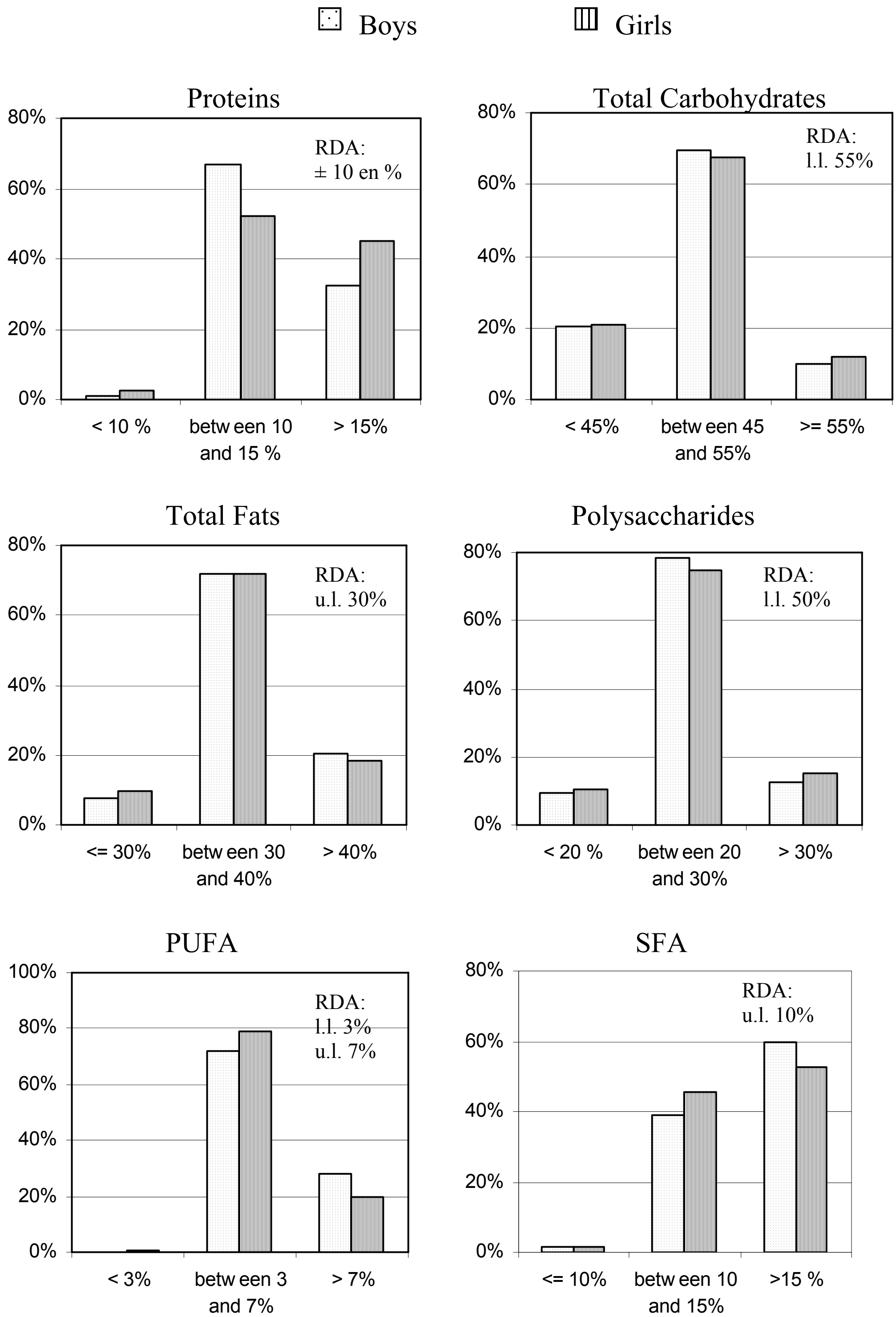

Figure 2.2: Energy contribution of some macronutrients compared to the lower and upper limits of the Belgian dietary recommendations.

PUFA: Poly Unsaturated Fatty Acids

SFA: Saturated Fatty Acids

l.l.: lower limit

u.p.: upper limit

Table 2.4: Mean overall energy contribution (in energy %) from macronutrients: recommended values as compared to the results of this study and a study of 25 years ago.

Reference	This study	Verdonk *et al*	Belgian Nutritional Recommendations
Period	1997	1978 – 79	
Survey Method	7d EDR	1d EDR	
Age (y)	13 – 18	13 – 19	
Boys			
N	129	235	
Energy (kcal)	2653 ± 516.2	3029 ± 1000	Age dependent
Energy (%)			
Protein	14.4 ± 2.03	12.7	10
CH, total	48.8 ± 4.98	49.0	55 – 75
Mono/disaccharides	23.9 ± 5.63	21.9	
Polysaccharides	24.9 ± 4.24	27.1	l. l. 50
Fat, total	36.2 ± 4.54	36.7	u. p. 30
SFA	15.5 ± 2.48	21.4	u. p. 10
MUFA	14.6 ± 2.20	10.3	
PUFA	6.1 ± 1.58	5.0	3 – 7
Girls			
N	212	363	
Energy (kcal)	1970 ± 450.9	2292 ± 849	Age dependent
Energy (%)			
Protein	14.9 ± 2.62	12.0	10
CH, total	49.2 ± 5.46	49.0	55 – 75
Mono/disaccharides	24.0 ± 6.01	22.9	
Polysaccharides	25.2 ± 4.64	26.1	l. l. 50
Fat, total	35.5 ± 4.96	38.1	u. p. 30
SFA	15.4 ± 2.45	21.6	u. p. 10
MUFA	14.2 ± 2.51	11.0	
PUFA	5.9 ± 1.46	5.6	3 – 7

EDR = Estimated Dietary Record; SFA = Saturated Fatty Acids; MUFA = Monounsaturated Fatty Acids; PUFA = Polyunsaturated Fatty Acids; l.l = lower limit; u.l. = upper limit

Figure 2.3 shows the mean proportional contribution from individual meals to the total intake of selected nutrients and to total energy intake. On average between 15 and 16% of the total energy intake comes from breakfast and about 32% comes from lunch; dinner represents on average 30.5%. The contribution of snacks varies between 20 and 24%. For most nutrients shown in these figures, the contribution from the different meals shows roughly the same pattern as the proportional energy contribution from these respective meals. An outlying observation concerns the very high supply of total carbohydrates and especially of mono/disaccharides from snacks (on average 42% of the total intake of mono/disaccharides vs. about 22% energy from snacks), resulting in a relatively lower supply of fat and protein from snacks. Compared with the boys, girls obtain proportionally more energy from snacks; this pattern is representative for all nutrients. Figure 2.3 also indicates an increasing contribution of mono/disaccharides from snacks with age, at least among boys, but there were no significant differences. The contribution of breakfast to the total intake of nutrients and to the total intake of energy decreases with age (13 – 15 vs. 16 – 18-y-old).

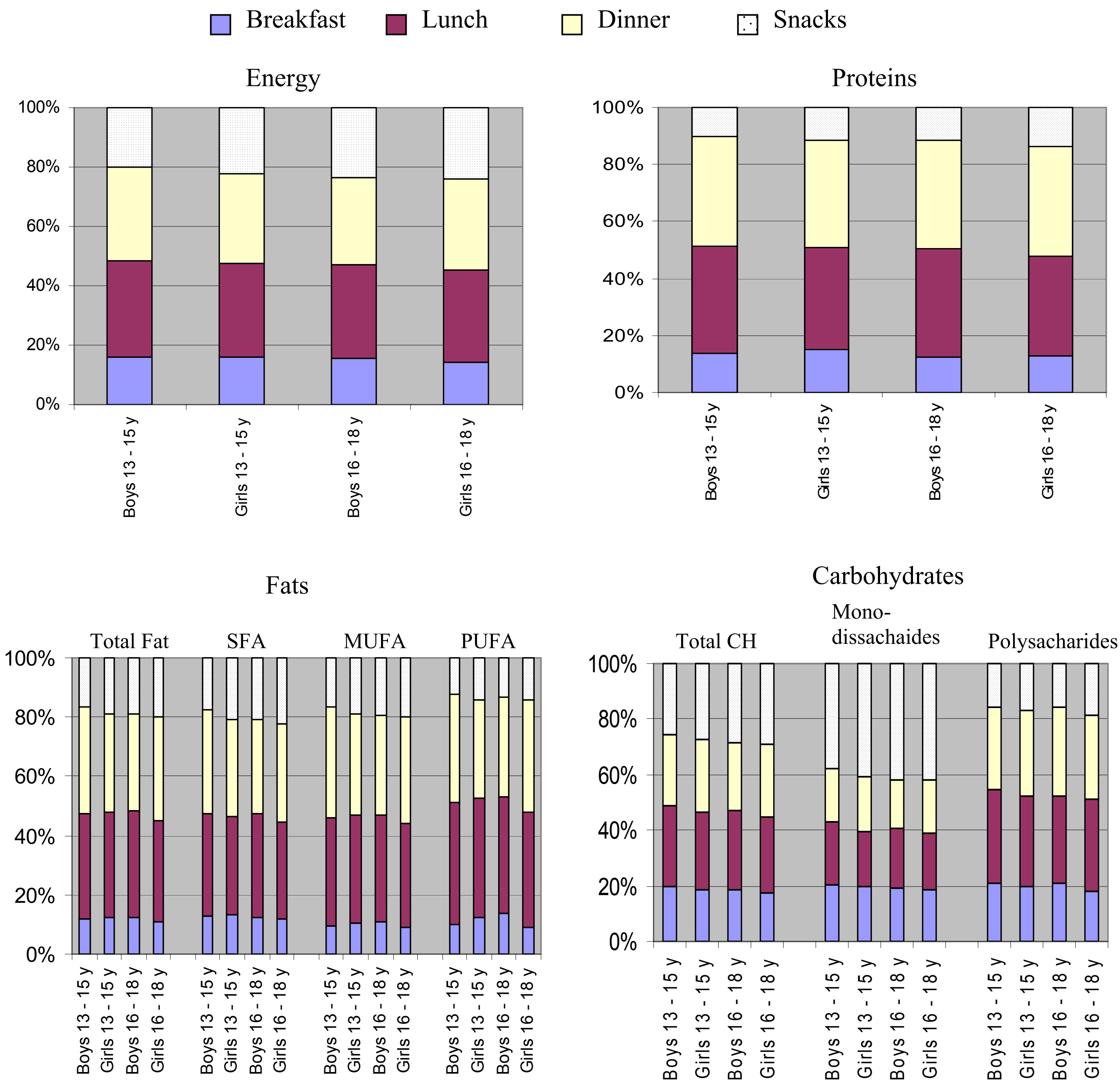

Figure 2.3: Mean proportional contribution from individual meals to the total intake of selected nutrients and to total energy intake by sex and age-group

Discussion

On the basis of the random sampling procedure and the reasonably high participation rate, the results in the present study can be considered representative for 13 – 18-y-old adolescents living in the region of Ghent. In both boys and girls, the participation rate among the vocational students was significantly lower than the participation rate of theoretical students (Table 1). It is not clear in what way this may have affected the results of the study. However, the anthropometrical data suggest a very small difference, if any, between the included and non-included subjects in overall nutritional status (Table 2).

In the present study a 7 day estimated dietary record was chosen because of the high respondent burden and time-consuming characteristic of weighed dietary food records. Estimated records are less accurate than weighed records of individuals' diets, but they have the same order of accuracy when ranking subjects into thirds or fifths (Bingham *et al*, 1988). On the other hand some validation studies express doubts about the use of a 7 day diet record as the method of choice for assessing total energy and nutrient intake in adolescents. The results of three studies (Bandini *et al*, 1990; Bratteby *et al*, 1998; Livingstone *et al*, 1992) indicate that the energy intake of adolescents is underestimated by ~20% by the diet record method. The most common reason for the observed bias in self-reported dietary intake methods is that the procedure is regarded as a burden, which probably promotes under-reporting of dietary intake (Bratteby *et al*, 1998). To avoid the issue of under-reporting, Goldberg, Black and colleagues (Black *et al*, 1991; Goldberg *et al*, 1991) developed a tool to detect the under-reporters. They calculated cut-off values based on the ratio of mean reported energy intake and basal metabolic rate, as estimated from weight and height using equations (Schofield *et al*, 1985), with the WHO recommended physical activity level for light activity (World Health Organization, 1985). Following the most specific method (cut-off 2) 15.5% of the study population, 7.8% of the boys and 20.3% of the girls, could be classified as probable under-reporters. Nevertheless the authors did not reject those subjects for the following reasons. Firstly, in the assumption that over-reporting is also present in the results, exclusion of the presumed under-reporters can bias the results as well (Black *et al*, 1991). An upper cut-off value exists but was derived rather arbitrarily (Livingstone *et al*, 1992) and was not used in this survey. Secondly, the calculation of the specific cut-off value requires specific information about the physical activity level of children or adolescents, which is not available in this study. In a recent study Black (2000) reports that, to identify diet reports of poor validity using the Goldberg cut-off, it is desirable to measure energy expenditure by doubly labelled water, heart rate monitoring or activity diary, and to make a direct comparison of energy intake and energy expenditure, thus avoiding the limitations of the cut-off value (Black, 2000). Thirdly, it has been suggested that low energy reporting may be just as common amongst those with plausible energy intakes as amongst those classically defined as under-reporters (Macdiarmid & Blundell, 1997), so that selectively excluding only those with implausible energy intakes could bias the results. Fourthly, the cut-off values are only appropriate for individuals who are in energy balance. Horwath (1991) reported that 13% of the investigated population, young female students, followed a weight-reduction diet at the time they were recording the diets (Horwath, 1991). It is likely that at any time a proportion of the subjects will be dieting, and may therefore provide diet records, which reflect their under-eating.

The sampling period was limited to 3 months, therefore it is not possible to describe seasonal effects.

The research team used the same method to recruit the study population as in a previous study (De Henauw *et al*, 1997), namely a multistage cluster sampling. A random sampling at the individual level would have been methodologically better, although the authors do not have arguments to assume that the procedure used in this study would introduce any measurable selection bias. The used dietary assessment method allows to characterize the study population reliable in terms of group means (which are used in all the tables).

Comparisons in dietary patterns of adolescents with other European countries have to be interpreted with caution as survey methods and populations can vary. Apparently, substantial variability in mean total energy intake can be observed across Europe. Swedish boys seem to have the lowest energy intakes (mean 10.2 MJ) (Samuelson *et al*, 1996). Average intakes reported in some other Western European countries are as follows: Belgium 11.1 MJ (this study), France 12.1 MJ (Hercberg *et al*, 1991), Germany 10.9 MJ (Kersting *et al*, 1998a) and England 11.4 MJ (Crawley, 1993). Differences in energy intake also seem to be accompanied by differences in the proportional distribution of the macronutrients. Swedish adolescents have a relatively low fat intake (Samuelson *et al*, 1996). Bergström *et al* (1993) reports that the decrease in fat intake among Swedish teenagers is mainly due to a shift to low energy spreads on bread and a lower intake of fat from dairy products, at the same time as cereal consumption is increasing.

Differences are also observed in the qualitative fat intake. In Spanish adolescents (Cruz, 2000) a dietary pattern rich in total fat (around 40% of the energy intake) is observed with a majority of monounsaturated fatty acids (around 18% of the energy intake). Meanwhile, the total fat contribution of Swedish adolescents (Bergström *et al*, 1993) accounts on average for 33% of the energy intake with a majority of saturated fatty acids (around 15% of the energy intake). The mean percentage of energy provided by total fat by Spanish adolescents is higher than in Belgium and Sweden, but the proportion of saturated fat is below the Flemish and Swedish value.

The energy contribution of proteins of German (Kersting *et al*, 1998a) and British (Crawley, 1993) boys and girls is lower than their Belgian counterparts, on average 12.5 vs. 14.6%, while the contribution of fat is higher than in the Belgian population, around 40 vs. 36%.

In Belgium, regional differences between a Walloon survey (Paulus *et al*, 2001) and the present study (Flanders) can be identified. Their comparison suggests that the energy intake is higher in the Walloon part than in the Flemish part of Belgium, respectively ±14.65 vs. ±10.88 MJ for boys and ±10.46 vs. ±8.37 MJ for girls. A lower relative contribution of proteins (about 2 E%) was observed in Wallonia, while the relative contribution of total carbohydrates is comparable. The proportional total fat intake was higher (on average 2 E%) in Wallonia than in Flanders, in both male and female adolescents. Comparing the fatty acids, a higher saturated fatty acid intake and a lower intake of unsaturated fatty acids could be noticed in Wallonia. Although the dissimilar methodologies in each survey (FFQ vs. 7 day food record), the differences are in line with results from a nationwide nutritional survey at the beginning of the eighties (Kornitzer & Bara, 1989), in which differences were observed between the north (Flanders) and the south (Wallonia): saturated fatty acids intake as well as nutritional cholesterol intake was higher in the south, whereas polyunsaturated fatty acids intake was higher in the north.

Comparing the results of this study with the current Belgian nutrient recommendations (Nationale Raad voor de Voeding, 1996) some important differences could be noted, although the overall energy intake seems to be adequate for both boys and girls. In both male and female adolescents, energy supply from proteins is on average 4 E% higher than the population recommended intake, while the relative contribution of carbohydrates is low, especially the intake of polysaccharides. In contrast, the mean intake of mono/disaccharides is proportionally very high and the relative fat intake is above the recommended intake, especially the saturated fatty acids.

The mono/disaccharies enter the diet through food items mostly of poor nutritional value, like sweets, sugar-sweetened drinks and cakes. These food items represent 50% of the intake of mono/disaccharides (data not shown). These poor nutritional food items (low nutrient density) are a source of concern. First, they have a high energy content, through mono/disaccharides, without providing essential nutrients and, according to a recent study (Ludwig *et al*, 2001), these kind of food items, especially sugar-sweetened drinks, are associated with obesity in children. A second source of concern is that adolescents have a more and more sedentary lifestyle (Deheeger *et al*, 1997), so less energy intake is necessary. A combination of high intake of these poor nutritional foods and lower energy requirements could lead to a low intake of essential micronutrients and increased risk of obesity.

Due to a lack of specific Belgian recommendations on fibre intake, an American recommendation is used, the 'age plus 5 – plus 10' rule (Williams, 1995). This rule reports that the actual total fibre intake should be between the age of the child plus 5 and the age plus 10, expressed in grams per day. Almost 50% of the boys had an intake lower than the recommended amount, while about 75% of the girls were below the lowest threshold. This is in line with the low intake of fruits and vegetables by adolescents (data not shown).

On the basis of the current Belgian dietary guidelines, total fat intake is considered too high, especially the intake of saturated fatty acids. Whether a further decrease in total fat intake is really necessary or could alternatively be replaced by a shift towards unsaturated fatty acids, is still under debate in scientific literature (Astrup *et al*, 2000; Bray & Popkin, 1998; Willett, 2000).

Some important changes occurred between 1978 (Verdonk study) and 1997 (this study); in both girls and boys the energy intake seems to have decreased in time and a shift in the proportional contribution of the macronutrients is observed. A more sedentary lifestyle is probably one of the reasons for the lower energy intake. On the other hand different types of methodologies and food composition databases could induce observed differences between the two surveys. A higher relative contribution of protein (about 2 E%) was noticed in the 1990s, while the relative contribution of total carbohydrates remained constant, although a higher contribution of mono/disaccharides could be identified for both boys and girls. The increase of availability of some specific food items like sweets and sugar-sweetened drinks could explain the higher intake of simple sugars. The increase in protein intake could be explained by a rise in available protein sources. The proportional total fat intake was higher in the 1970s in female adolescents and remained constant in male adolescents. On the other hand a strong decrease between the 1970s, and the 1990s, of saturated fatty acids could be detected, while mean MUFA and PUFA intake increased.

Currently there are no Belgian recommendations concerning the distribution of energy intake over the day. Even in scientific literature it is difficult to find clearly described definitions of the energy contribution of each meal. In Sweden recommendations have been developed: breakfast 20 –25% of daily energy intake, lunch and dinner 25 –35% and the rest as two to three snacks between meals (Bergström *et al*, 1993). The meal pattern in the present study was quite different. A lower energy intake at breakfast was found while a higher proportion of energy was derived from snacks. Snacks are often considered to be of lower nutritional quality than the other meals. This consideration was reflected in the high mono/disaccharide content, but the fat content was lower compared with lunch and dinner. The same pattern was established in a Flemish primary schoolchildren study (De Henauw *et al*, 1997). Lunch and dinner are very rich in fat; this indicates that nutritional campaigns aiming at altering the fat intake should focus on these meal occasions.

In conclusion, this study shows clearly that the pattern of macronutrient intake of Flemish adolescents differs from the current Belgian dietary recommendations. In particular, the mean intake of fat and mono/disaccharide is higher than recommended. Snacks were found to be an important source of mono/dissacharides and saturated fatty acids, while energy intake from breakfast was on average very low. It can be concluded that further efforts are needed in order to improve the dietary habits in young Flemish adolescents.

3

RELATIONSHIP BETWEEN BREAKFAST HABITS AND OVERALL DIET OF ADOLESCENTS

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Public Health Nutrition; Submitted

Abstract

Objective: To describe breakfast consumption patterns, on nutrient and food item level, in Belgian adolescents.

Design: A 7-day estimated food record was administered in a cross-sectional survey.

Setting: Secondary schools in Ghent, Belgium.

Subjects: A total of 341 adolescents (13 – 18 y), multistage clustered sampling.

Results: The energy contribution of the breakfast to the daily energy intake is on average 15.7 energy percent in boys and 14.9 energy percent in girls. Significantly more overweight girls and significantly more girls following a vocational training were categorised having a low quality breakfast. In boys, the energy contribution of polysaccharides is significantly higher in good quality breakfast consumers. The intake of all selected micronutrients is significantly higher in good quality breakfast consumers. In girls, the total energy intake, the proportional intake of proteins and polysaccharides is significantly higher in good quality breakfast consumers while the proportional contribution of total fat, monounsaturated and polyunsaturated fatty acids is significantly lower in these girls. The intake of all micronutrients is significantly higher in good quality breakfast consuming girls. In all adolescents, good quality breakfast consumers have a significantly higher intake of bread, fruit, vegetables, milk & milk products and fruit juice while intake of soft drinks is significantly lower than low quality breakfast consumers.

Conclusions: Good quality breakfast consumers had a better overall dietary pattern – on nutrient and food group level – than low quality breakfast consumers. A daily breakfast, including whole grains products, fruit and (semi-)skimmed milk products or an alternative source of calcium is recommended.

Introduction

Breakfast is widely being promoted as essential for the nutritional well-being of children. Breakfast skipping is associated with health-compromising behaviours in adults and adolescents (Keski-Rahkonen *et al*, 2003). Breakfast consumers tend to have higher intakes of micronutrients and lower intake of fat and are more likely to have a better overall diet quality (Rampersaud *et al*, 2005; Ruxton & Kirk, 1997). The consumption of breakfast has been positively associated with enhanced cognitive and academic performance, psychosocial function and school attendance (Pollitt, 1995; Pollitt & Mathews, 1998). Although, other studies indicate that cognitive performance is relatively robust to short-term fasting in relatively well-nourished children (Rogers, 1997). Aranceta and co-workers stated that it is not clear to what extent breakfast contributes to a better cognitive performance in school. Learning is a complex process resulting from multiple interactions (Aranceta *et al*, 2001). However, a recent review stated that breakfast may possibly benefit cognitive function but the interpretation of the results can be complicated by confounding factors such as social and educational variables (Rampersaud *et al*, 2005).

It has been reported that routinely eating breakfast may be associated to more regular eating habits and exercise patterns, healthful food choices, and consisted energy intake, which when taken together contribute to a reduced BMI (Affenito *et al*, 2005). Eating a healthy breakfast is important to adolescents’ health needs in general. Breakfast provides an ideal opportunity for adolescents to begin the day by eating bread, other cereals, fruit, which are all important elements of a healthy and balanced diet. The importance of breakfast consumption in relation to nutritional balance is shown in different subpopulations (Aranceta *et al*, 2001; Morgan *et al*, 1986b; Navia *et al*, 1997). Despite the benefits of breakfast consumption, it is the meal most often skipped by adolescents (Sjoberg *et al*, 2003).

In the present paper breakfast consumption patterns, on nutrient and food item level, in Belgian adolescents are described. The analyses reported in this paper must be situated within a broad context of a search for elements that may be helpful for developing strategies to implement the translation of nutrient dietary guidelines into food and meal based dietary guidelines.

Material and methods

The data presented in this paper were obtained from a cross-sectional dietary survey, carried out in an adolescent population (males and females aged 13-18 years) in the region of Ghent (Belgium) in the spring of 1997. The sampling design and the methodology of the field work have been described in detail elsewhere (Matthys *et al*, 2003). In brief, a random sample of 341 adolescents (129 boys and 212 girls) – selected from all educational levels in the Belgian secondary school system – completed a 7-day food record (consecutive) under rigorous conditions of quality control carried out by experienced dieticians.

A 7-day estimated food record method (semi-structured diary) was used to quantify food and nutrient intake. Information on the type (including brand names) and amount of food consumed was collected through an open entry format. Instructions for the completion of the diary and regular checks for quality and completeness of the diaries were carried out by experienced dieticians. In the diaries, days were truncated into six eating moments, namely breakfast, lunch, dinner and snacks (divided in morning, afternoon and late-evening snacks). The point of time a certain meal or food item was consumed had to be indicated. Breakfast was defined as the first eating occasion involving a solid food or a beverage that occurred after waking and was consumed between 6 a.m. and 10 a.m. during weekdays and between 6 a.m. and 11 a.m. for the weekends and holidays.

Nutrient composition data used in the current study are those from the Belgian and the Dutch food composition tables (NEVO, 1993; NUBEL, 1992; NUBEL, 1995). Calculation of nutrients was done by means of a nutritional software package developed by the Unilever company in the Netherlands (Rampersaud *et al*, 2005). Average nutrient and food intakes were calculated as the mean of the 7-day intake period. Food items were classified in different food groups according to the Dutch Food Composition Table (NEVO, 1993).

For the sake of the analyses in this paper, a concise characterisation of the breakfast habits at the level of the individual was undertaken. This characterisation included both qualitative and quantitative aspects of breakfast. Qualitative aspects of breakfast were related to presence or absence (in relevant amounts) of food items of three specific food groups (further called “target food groups”): cereal products, dairy products and fruits/vegetables. Quantitative aspects of breakfast included both frequency of breakfast use and the relative contribution of the target food groups to the total daily energy from breakfast.

Qualitative and quantitative aspects of breakfast were combined into a so-called “individual breakfast score” on the basis of the following consecutive steps.
In a first step, every single breakfast from all diaries was characterised in a qualitative way. For that purpose, 14 different labels were developed on the basis of different combinations of food groups present in the breakfast and the amount of energy they represented. These 14 labels were subsequently recoded into five specific “**individual breakfast labels”** (see Table 3.1).

Table 3.1: Individual breakfast label and individual breakfast score.

Individual Breakfast Label		Individual Breakfast Score	
Number	Explanation	Number	Explanation
Label 1	no breakfast or very limited breakfast (< 400 kJ)	Score 1	subjects that never take any breakfast of any significance (sum-score 7-10)
Label 2	breakfast including only energy containing beverages	Score 2	subjects that usually don’t take breakfast of any significance (sum-score 11-14)
Label 3	breakfast including food items from one of the target food groups, potentially in combination with a non-dairy fat or protein source	Score 3	subjects that either usually have breakfast of low nutritional value or only occasionally have breakfast of higher nutritional value (sum-score 15-21)
Label 4	breakfast including food items from two of the target food groups, potentially in combination with a non-dairy fat or protein source	Score 4	Subjects that usually take breakfast of good/excellent nutritional value (sum-score 22-29)
Label 5	breakfast including food items from the three target food groups, potentially in combination with a non-dairy fat or protein source	Score 5	Subjects that eat good/excellent quality breakfast practically every day (sum-score 30-35)

In a second step, the “individual breakfast labels” were summed up for all days included in the food diary, resulting in a potential overall range of sum-labels from a minimum of 7 (individual breakfast label of 1 for all days in the food diary) up to a maximum of 35 (individual breakfast label of 5 for each day in the food diary). From this "sum-score", a final "**individual breakfast score**" was assigned to all 341 subjects in the study (see Table 3.1).

For this study, the five individual breakfast score categories for breakfast habits were dichotomised into a group who "never takes breakfast or takes a low-quality breakfast, i.e. not enough calories and/or not enough variation in foods" (group 1, score 1-3) and a group who "takes good/excellent quality breakfast (nearly) every day" (group 2, score 4-5).

The ratio of energy intake over the basal metabolic rate (EI/BMR) was calculated to have an indication of the quality of reporting (Goldberg *et al*, 1991).

Statistical analysis was done with the SPSS software version 12 (SPSS, Inc., Chicago, IL, USA). Descriptive statistics used means and standard deviations for continuous data. Test for normality were performed, using a Kolmogorov – Smirnov test. Student's t-tests or Mann-Whitney U tests were used to compare the means of the different groups. In order to search for potential confounders the number of adolescents in different categories of body mass index (BMI) (Cole *et al*, 2000) and education – 'general' education (mainly theoretical courses) and vocational training (based on practical skills) – in the different breakfast classifications were compared by use of a Fisher's Exact test. A value of < 0.05 was taken as threshold for significance.

The study was approved by the Ethical Committee of the Ghent University Hospital.

Results

The energy contribution of the breakfast to the daily energy intake is on average 15.7 energy percent in boys and 14.9 energy percent in girls. A restricted number of boys and girls have a breakfast energy contribution of above 25%, respectively 9.7% in boys and 5.7% in girls. Figure 3.1 shows the distribution of the energy contribution of breakfast in both, boys and girls.

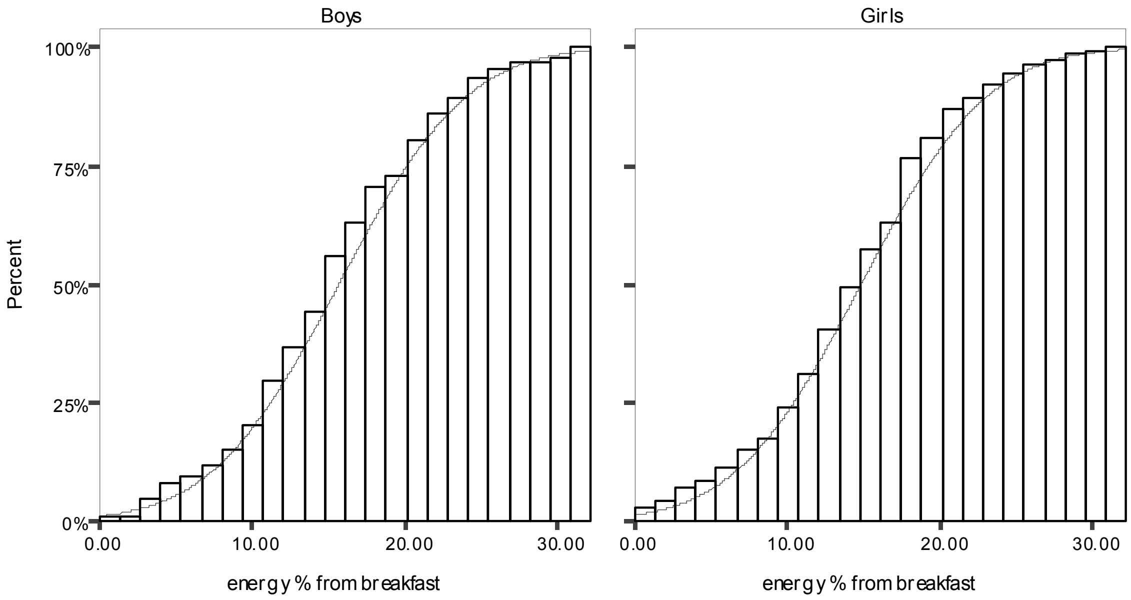

Figure 3.1: Cummulative histogram of energy percentage from breakfast in boys and girls.

Overall, the individual breakfast score was below three – take never or usually do not take breakfast – for 13.2% of the boys and for 16.9 % of the girls. In boys, about 18 % takes a low-quality breakfast (score 3), about 56% takes a "moderate to good quality breakfast" (score 4) while only 13% takes a full value breakfast (score 5). In girls, about 27% have an individual breakfast score of 3 and about 45% have a score of 4 and only 10% had an individual breakfast score of 5.

Table 3.2 presents the number of adolescents in different categories of BMI and education, the mean age and mean EI/BMR according to the different breakfast categories. In both boys and girls, a higher number of subjects were identified as good quality breakfast eaters. In boys, the age of low quality breakfast eaters is significantly higher than the good quality breakfast eaters. In girls, the mean EI/BMR ratio is significantly lower in low quality breakfast consumers than in the subjects identified with a good quality breakfast. In boys no differences were found between breakfast categories according to the BMI and educational training. Significantly more overweight girls and significantly more girls following a vocational training were categorised having a low quality breakfast.

Table 3.2: The mean (SD) age, mean (SD) ratio of EI/BMR and the number of adolescents in different categories of BMI and education according to their breakfast habit (low or good quality).

	Boys (n=129)		P-value	Girls (n=212)		P-value
	Low	Good		Low	Good	
N	40	89		94	118	
Age (years) [a]	16 (1)	15 (1)	0.013	16 (1)	16 (1)	0.482
EI/BMR [a]	1.49 (0.33)	1.59 (0.29)	0.130	1.27 (0.37)	1.43 (0.28)	<0.001
BMI [†,Γ, b]			>0.999			0.029
Normal	38	83		73	105	
Overweight	2	6		19	11	
Education [b]			0.400			<0.001
General	33	79		25	76	
Vocational	7	10		69	42	

[†] BMI categories according to Cole *et al*, 2000
[Γ] Data of 4 girls are missing
[a] Mann-Whitney U test
[b] Fisher's Exact test

In Table 3.3 the energy intake at breakfast, the energy contribution of macronutrients to the total energy supplied by breakfast and micronutrient intake at breakfast according to their breakfast habit are shown. In both, boys and girls, the energy intake and the proportional contribution of proteins are significantly higher in subjects having a good quality breakfast. Girls who consume a good quality breakfast have a significantly higher proportional intake of polysaccharides than the low quality breakfast consumers. In both, boys and girls, the intake at breakfast of the selected micronutrients is significantly higher in the subjects consuming a good quality breakfast.

In Table 3.4 total energy intake, the energy contribution of macronutrients to the total energy intake and micronutrient intake according to their breakfast habit are presented. In boys, there is no significant difference in the total energy intake between the two kinds of breakfast consumers. The energy contribution of polysaccharides is significantly higher in good quality breakfast consumers. The intake of monounsaturated and polyunsaturated fatty acids is lower in good quality breakfast consuming adolescents. The intake of all selected micronutrients is significantly higher in good quality breakfast consumers. In girls, the total energy intake is significantly higher in good quality breakfast consumers. The proportional intake of proteins

and polysaccharides is significantly higher in the female good quality breakfast consumers while the proportional contribution of total fat, monounsaturated and polyunsaturated fatty acids is significantly lower in these girls. The intake of all micronutrients is significantly higher in good quality breakfast consuming girls. In girls, the relative micronutrient intake (expressed as mg/1000 kcal) is significantly higher in good quality breakfast consumers (data not shown).
In boys, the differences are not always significant but a similar trend is found.

The intake of different food groups is presented in Table 3.5. In both, male and female adolescents who consume a good quality breakfast have a significantly higher intake of bread, fruit, vegetables, milk & milk products and fruit juice while their intake of soft drinks is significantly lower than low quality breakfast consumers. In girls, a larger number of differences are found. Female good quality breakfast consumers also have a significantly higher intake of cereal products, cheese and water.

In Table 3.6 total energy intake of the diet without breakfast, the energy contribution of macronutrients to the total energy intake of the diet without breakfast and micronutrient intake of the diet without breakfast according to their breakfast habit are presented. In boys, there are no significant differences in the total energy intake and macronutrient intake. The intake of calcium, magnesium and vitamin C is significantly higher in good quality breakfast consumers. In girls, the proportional intake of proteins is significantly higher in the female good quality breakfast consumers while the proportional contribution of and monounsaturated fatty acids is significantly lower in these girls. The intake of all micronutrients is significantly higher in good quality breakfast consuming girls.

Table 3.3: Energy intake (kcal) (mean (SD)) at breakfast, contribution of macronutrients (as energy percentage) (mean (SD)) to the total energy supplied at breakfast and micronutrient intake (mg) (mean (SD)) at breakfast according to their breakfast habit (low or good quality).

	Boys (n=129)		P-value[a]	Girls (n=212)		P-value[a]
	Low (n=40)	Good (n=89)		Low (n=94)	Good (n=118)	
Energy	274.8 (161.91)	478.3 (164.38)	< 0.001	196.3 (113.89)	371.8 (119.34)	<0.001
Protein	10.7 (4.56)	12.4 (2.81)	0.022	12.1 (6.42)	14.1 (3.47)	<0.001
Carbohydrates, total	59.4 (15.17)	61.2 (8.46)	0.643	57.9 (18.34)	60.1 (9.20)	0.335
Mono- & disaccharides	32.3 (16.43)	30.6 (8.57)	0.699	34.3 (20.08)	30.3 (9.76)	0.389
Polysaccharides	26.8 (12.51)	30.1 (8.18)	0.278	23.4 (15.36)	29.7 (9.62)	0.002
Fat, total	27.3 (12.98)	26.3 (8.07)	0.492	25.6 (13.06)	25.7 (7.71)	0.519
SFA	12.4 (6.96)	11.2 (4.50)	0.562	11.1 (6.26)	11.3 (4.44)	0.941
MUFA	8.7 (5.08)	8.3 (3.20)	0.533	8.4 (4.98)	8.0 (3.05)	0.334
PUFA	3.8 (3.62)	3.9 (2.83)	0.418	3.9 (3.30)	3.5 (1.90)	0.775
Calcium	112.7 (98.86)	261.5 (145.54)	<0.001	108.1 (105.60)	248.5 (147.35)	<0.001
Phosphorus	154.8 (111.99)	323.1 (144.62)	<0.001	125.6 (107.44)	291.9 (157.57)	<0.001
Iron	1.6 (1.11)	2.7 (1.40)	<0.001	0.9 (1.03)	2.1 (1.16)	<0.001
Magnesium	33.1 (22.64)	66.8 (30.25)	<0.001	25.7 (17.71)	56.8 (27.54)	<0.001
Thiamin	0.2 (0.11)	0.3 (0.19)	<0.001	0.1 (0.12)	0.3 (0.16)	<0.001
Riboflavin	0.2 (0.19)	0.5 (0.31)	<0.001	0.2 (0.21)	0.5 (0.29)	<0.001
Vitamin C	3.2 (8.61)	17.1 (25.95)	<0.001	7.9 (14.28)	18.1 (21.27)	<0.001

SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids
[a] Mann-Whitney U tests

Table 3.4: Total energy intake (kcal) (mean (SD)), contribution of macronutrients (as energy percentage) (mean (SD)) to the total energy and micronutrient intake (mg) (mean (SD)) according to their breakfast habit (low or good quality).

	Boys (n=129)		P-value	Girls (n=212)		P-value
	Low (n=40)	Good (n=89)		Low (n=94)	Good (n=118)	
Energy	2603.9 (577.33)	2674.8 (488.20)	0.502	1841.2 (494.96)	2072.9 (384.72)	< 0.001
Protein	13.9 (1.84)	14.6 (2.08)	0.058	14.1 (2.71)	15.5 (2.37)	< 0.001
Carbohydrates, total	47.8 (5.28)	49.2 (4.81)	0.140	48.7 (6.06)	49.6 (4.92)	0.266
Mono- & disaccharides	22.0 (6.74)	22.7 (5.04)	0.596	22.6 (7.02)	22.7 (4.86)	0.831
Polysaccharides	22.0 (4.06)	24.0 (4.36)	0.016	22.9 (5.17)	24.4 (4.22)	0.025
Fat, total	36.8 (4.64)	35.9 (4.49)	0.327	36.5 (5.44)	34.6 (4.39)	0.005
SFA	14.6 (2.54)	14.6 (2.33)	0.990	14.6 (2.42)	14.3 (2.22)	0.386
MUFA	14.3 (2.30)	13.6 (2.17)	0.120	14.1 (2.81)	12.7 (2.17)	< 0.001
PUFA	6.0 (1.48)	5.7 (1.59)	0.288	5.9 (1.62)	5.4 (1.25)	0.005
Calcium	739.9 (277.44)	991.4 (351.52)	< 0.001	638.3 (278.96)	937.8 (347.02)	< 0.001
Phosphorus	1315.6 (291.61)	1543.3 (363.79)	0.001	979.9 (283.37)	1304.5 (373.22)	< 0.001[a]
Iron	12.6 (2.64)	13.8 (2.97)	0.035	8.9 (2.45)	10.9 (2.75)	< 0.001
Magnesium	233.9 (52.30)	288.1 (70.28)	< 0.001	179.2 (48.49)	242.3 (65.30)	< 0.001
Thiamin	1.3 (0.37)	1.6 (0.87)	0.004[a]	0.9 (0.74)	1.3 (1.00)	< 0.001[a]
Riboflavin	1.4 (0.39)	1.8 (0.58)	< 0.001	1.1 (0.53)	1.5 (0.56)	< 0.001
Vitamin C	56.5 (27.80)	94.5 (51.88)	< 0.001[a]	64.1 (42.64)	89.5 (46.35)	< 0.001[a]

SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids

[a] Mann-Whitney U tests

Table 3.5: Intake of some food groups (g/day) in adolescents according to their breakfast habit (low or good quality).

	Boys (n=129)				P-value[a]	Girls (n=212)				P-value[a]
	Low (n=40)		Good (n=89)			Low (n=94)		Good (n=118)		
	Mean (SD)	Median	Mean (SD)	Median		Mean (SD)	Median	Mean (SD)	Median	
Potatoes	159.2 (74.42)	149.29	140.1 (84.33)	127.86	0.094	106.8 (58.46)	98.14	95.8 (53.11)	90.11	0.152
Bread, rusk & breakfast rolls	172.2 (69.97)	170.43	206.3 (77.27)	193.57	0.028	123.1 (51.08)	124.64	165.7 (50.81)	162.64	< 0.001
Egg	12.3 (12.64)	12.11	7.6 (8.86)	4.29	0.116	8.9 (10.26)	4.50	9.7 (12.77)	5.89	0.838
Fruit	61.6 (74.31)	33.21	95.2 (71.30)	71.86	0.002	84.1 (87.94)	68.00	138.6 (101.61)	117.14	< 0.001
Cakes & biscuits	32.6 (33.46)	20.57	39.6 (29.34)	33.43	0.070	29.2 (23.73)	24.39	32.1 (26.47	24.86	0.515
Poultry	28.2 (23.63)	21.43	29.6 (31.59)	22.86	0.693	22.9 (24.26)	17.86	23.2 (22.81)	18.79	0.782
Cereal products & binding agents	50.8 (40.33)	46.68	66.7 (59.76)	58.14	0.245	37.8 (43.02)	25.11	56.9 (43.99)	47.64	<0.001
Vegetables	111.5 (60.54)	100.46	131.3 (64.72)	120.86	0.048	90.5 (55.43)	75.39	116.0 (57.26)	107.71	0.001
Cheese	25.8 (24.49)	17.14	26.5 (23.59)	19.00	0.766	22.1 (21.14)	15.07	31.1 (21.65)	30.14	0.001
Milk & milk products	165.6 (127.77)	120.07	318.1 (229.66)	292.00	< 0.001	152.7 (167.21)	110.86	307.8 (239.60)	251.96	< 0.001
Nuts, seeds & snacks	20.2 (21.85)	15.18	15.3 (19.15)	8.00	0.238	13.6 (17.07)	8.57	10.8 (12.65)	7.93	0.438
Sugar, confectionary, sweet fillings & sweet sauces	42.6 (37.07)	32.00	48.9 (33.75)	39.43	0.164	32.7 (23.46)	25.14	32.9 (23.15)	27.79	0.646
Fats, oils & savoury sauces	52.8 (23.77)	53.07	49.9 (27.33)	46.36	0.288	37.2 (20.62)	33.00	33.3 (15.73)	31.54	0.277
Fish & fish products	16.8 (21.77)	10.00	18.6 (22.22)	14.29	0.772	13.6 (15.64)	8.57	15.5 (17.55)	9.29	0.581
Meat & Meat products	152.3 (45.88)	144.25	141.8 (60.92)	140.00	0.335	88.9 (48.82)	88.57	94.9 (49.63)	86.57	0.313
Water	380.1 (424.41)	208.96	457.5 (370.08)	406.79	0.078	411.9 (345.91)	326.50	559.9 (367.16)	517.57	0.002
Soft drinks	636.3 (413.14)	608.57	361.7 (291.16)	322.86	< 0.001	317.7 (310.26)	215.00	170.6 (192.89)	104.29	< 0.001
Fruit juice	68.1 (107.45)	28.57	171.4 (187.73)	130.00	0.001	106.1 (146.45)	57.14	166.0 (148.31)	142.86	< 0.001

[a] Mann-Whitney U tests

Table 3.6: Total energy intake (kcal) (mean (SD)) of the diet without breakfast, contribution of macronutrients (as energy percentage) (mean (SD)) to the total energy of the diet without breakfast and micronutrient intake (mg) (mean (SD)) of the diet without breakfast according to their breakfast habit (low or good quality).

	Boys (n=129)		P-value	Girls (n=212)		P-value
	Low (n=40)	Good (n=89)		Low (n=94)	Good (n=118)	
Energy	2329.2 (549.37)	2196.6 (437.29)	0.183	1644.9 (460.34)	1701.1 (347.33)	0.312
Protein	14.3 (2.05)	15.1 (2.36)	0.054	14.3 (2.88)	15.8 (2.63)	< 0.001
Carbohydrates, total	46.5 (5.38)	46.6 (4.77)	0.963	47.5 (6.08)	47.3 (5.36)	0.838
Mono- & disaccharides	21.1 (7.15)	21.0 (5.27)	0.906	21.3 (7.21)	21.1 (5.22)	0.805
Polysaccharides	21.3 (4.39)	22.6 (4.20)	0.090	22.5 (5.40)	23.3 (4.41)	0.275
Fat, total	37.5 (4.59)	38.0 (4.39)	0.539	37.5 (5.39)	36.5 (4.78)	0.144
SFA	14.7 (2.39)	15.4 (2.43)	0.154	14.8 (2.36)	14.9 (2.33)	0.819
MUFA	14.8 (2.35)	14.7 (2.22)	0.901	14.6 (2.95)	13.8 (2.37)	0.022
PUFA	6.1 (1.45)	6.0 (1.66)	0.702	6.1 (1.69)	5.7 (1.32)	0.105
Calcium	627.1 (246.44)	729.9 (276.17)	0.046	530.2 (226.24)	689.3 (258.51)	< 0.001
Phosphorus	1160.8 (246.76)	1220.2 (291.34)	0.265	854.3 (231.81)	1012.6 (272.25)	< 0.001
Iron	11.1 (2.31)	11.1 (2.36)	0.924	8.0 (2.16)	8.8 (2.23)	0.005
Magnesium	200.8 (43.77)	221.2 (55.45)	0.041	153.5 (40.68)	185.5 (51.07)	< 0.001
Thiamin	1.1 (0.33)	1.3 (0.85)	0.490[a]	0.9 (0.72)	1.1 (0.98)	< 0.001[a]
Riboflavin	1.2 (0.32)	1.3 (0.42)	0.236	0.9 (0.39)	1.1 (0.38)	< 0.001[a]
Vitamin C	53.3 (25.39)	77.4 (40.83)	< 0.001[a]	56.1 (39.03)	71.4 (37.06)	< 0.001[a]

SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids
[a] Mann-Whitney U tests

Discussion

The Iowa Breakfast Study carried out in the United States at the beginning of the 1960s was one of the first studies that addressed the importance of the role of breakfast in dietary balance, physical and cognitive performance (Cereal Institute Inc, 1962). To the knowledge of the authors, the present study is the first Belgian research on the relationship between breakfast parameters and the overall diet of adolescents. The current study found that good quality breakfast consumers had a better overall dietary pattern – on nutrient and food group level – than low quality breakfast consumers. However, one could not relate the current differences in dietary intake to nutrient status due to the lack of biochemical assays of cholesterol, vitamin and mineral status. Nevertheless, the associations between breakfast patterns and biomarkers of nutrient status are not widely reported and inconsistent. Preziosi and colleagues only found a significantly higher thiamine blood concentration in adolescents consuming high-energy breakfasts (Preziosi *et al*, 1999).

In the current study individual breakfast labels and scores were computed. These breakfast scores were based on both nutrient and food item recommendations. However, there is no general scientific agreement as to which foods have to be consumed and in what amounts. Therefore the current rationale for the development of the scores is based, for food items, on the guidelines for a healthy breakfast in school children (Pérez-Rodrigo *et al*, 2000; Vlaams Instituut voor Gezondheidspromotie, 2003) and according to some investigators an ideal breakfast should provide at least 25% of the recommended daily energy (Morgan *et al*, 1981; Morgan *et al*, 1986b). This recommendation is based on the mentioned Iowa Breakfast Study (Cereal Institute Inc, 1962). By introducing a breakfast score the authors are aware that a limitation could be introduced due to the loose of information about the heterogeneity and variability of the breakfast consumption pattern of all adolescents, this within and between the good and low quality breakfast consumers. As the classification method can group subjects with widely differing intakes into one category and subjects with very similar intakes into different categories if they are close to the cut-off point, this misclassification of subjects could introduce difficulties in the interpretation of the results. Another possible disadvantage of the used breakfast score algorithm is that a subject receives a lower score when he/she does not consume only one of the proposed foods. However, the strength of the current study is the use of the 7-day dietary record, which reflects the usual dietary intake and reflects in that way the usual breakfast consumption of the different participants. It is not clear how the possible impact of the mentioned possible limitations may have affected the results of the study.

The importance of breakfast in assuring adequate nutrient intakes in children and adolescents has been documented in different studies (Aranceta *et al*, 2001; Baric & Satalic, 2002; Hercberg *et al*, 1996; Ortega *et al*, 1998a; Preziosi *et al*, 1999). The current findings, good quality breakfast consumers have a better overall dietary pattern than low quality breakfast consumers, are in line with these European studies. However, an inherent problem with comparing different breakfast studies are the methodological differences regarding dietary intake data collection and how breakfast is defined (types, amounts, categories). These inconsistencies should be kept in mind when comparing different studies. In the current study female good quality breakfast consumers have a higher energy intake, while no difference was found in boys. In the Göteborg Adolescence Study (15 – 16 years) a similar trend was found, female adolescents with breakfast on a regular basis had significantly higher energy intake compared to those with irregular breakfast intake (Sjoberg *et al*, 2003). In the current study, female good quality breakfast consumers have a relative higher intake of total protein, polysaccharides and a relative lower intake of total fat, MUFA and PUFA. In boys, only a relative higher intake of polysaccharides in good quality breakfast consumers was found. In a French study conducted in adolescents (10 – 18 years) high-energy breakfast consumers (> 25% of energy from breakfast) have higher total daily intakes (expressed as energy percentage) of carbohydrates but lower intake of total fat and saturated fat (Preziosi *et al*, 1999). Swedish regular breakfast consumers have a higher relative intake of total protein and a relative lower intake of sucrose (Sjoberg *et al*, 2003). However, in the literature conflicting results can be found, De Graaf and co-workers showed that neither energy content nor macronutrient composition of breakfast had any effect on energy and macronutrient intake consumed over the rest of the day (De Graaf *et al*, 1992). In the current study, there is no difference in the intake of saturated fatty acids (expressed as energy percentage) while the intake of energy is higher in good breakfast consumers. In girls, this results in a higher absolute saturated fatty acid intake of more or less 3 grams. It is well known that saturated fatty acids have the capacity to raise the serum cholesterol (Keys & Parlin, 1966). However, it is not known to what extent this affects the overall dietary pattern of good quality breakfast consumers, taken into account other dietary factors (micronutrients, consumption of fruit and vegetables). Good quality breakfast consumers have higher intake of micronutrients at breakfast and during other meals of the day. In a French, Spanish and Swedish adolescent population, the intake of vitamin C, thiamine, riboflavin, calcium, iron and zinc was higher in regular breakfast consumers (Sweden) or high-energy breakfast consumers (France, Spain) (Ortega *et al*, 1998a; Preziosi *et al*, 1999; Sjoberg *et al*, 2003). Adolescents with a low quality breakfast seem not to be able to make up the low micronutrient intake at other meals during the day. In a recent review all above findings are reflected and it is clear that there is evidence that breakfast consumption significantly contributes to the overall diet nutrient adequacy (Rampersaud *et al*, 2005).

In the current study, in girls, the group who consume a good quality breakfast is associated with a lower proportion of overweight adolescents, despite the higher daily energy intake. Skipping breakfast is a popular method of losing weight among adolescents (Lattimore & Halford, 2003) and it is shown that adolescents who has the perception of a too high body weight may be more likely to skip breakfast (Sjoberg *et al*, 2003). Skipping of breakfast may lead to hunger in the morning and result in an increased snacking. From a public health point of view this phenomenon of increased snacking should be associated with a higher consumption of whole grain products, fruit, vegetable and water, unfortunately snack foods commonly consumed by adolescents tend to be high in added sugars, fat and low in minerals and vitamins. This could be associated to a less healthy dietary pattern. At the same time, the food availability at schools could play a role in this increased consumption of 'empty calories'. A recent study showed that the majority of the available food items at schools, supplied by school shops or vending machines, could be categorised as 'empty calories' (Vereecken *et al*, 2005a). According to these mechanisms – skipping breakfast, increase of snacking 'empty calories', availability of poor quality food items, weight gain – adolescents could come into a 'vicious circle'. However, based on several cross-sectional studies no uniform association between breakfast skipping and higher weights or body mass index is found in adolescents (Rampersaud *et al*, 2005). Although, some studies state that breakfast consumption is part of a weight-reduction programme (Schlundt *et al*, 1992) and it is one of the factors affecting weight loss maintenance in adults (Elfhag & Rossner, 2005).

However until now, to the knowledge of the authors, there have been no randomised controlled trials investigating breakfast consumption and weight control in adolescents. Breakfast consumption, a regular meal rhythm and an increase of feeding frequencies seem to have a positive impact on weight management (Louis-Sylvestre *et al*, 2003). However, there is no scientific consensus about specific recommendations concerning meal frequency and health outcomes (Gibney & Wolever, 1997; Mattson, 2005).

Good quality breakfast consumers tend to be associated with making more healthful food choices during the day, such as the consumption of more vegetables, fruit, milk & milk products, water and a lower consumption of soft drinks. The significantly higher intake of milk & milk products and cheese in female good quality breakfast consumers are possibly the main contributors of the higher saturated fatty acid intake. A similar pattern is found in Swedish adolescents, girls with irregular breakfast and lunch intake have a less healthy food choice and consume more soft drinks and less milk, vegetables and fruit (Sjoberg *et al*, 2003). Several studies have mentioned the importance of ready-to-eat breakfast cereals, the nutritional benefits of these cereals are associated with improved compliance with dietary recommendations and improved nutrient status based on biochemical measures (Galvin *et al*, 2003; Gibson, 2003). In the current study, less than 50 % of the adolescents consume ready-to-eat breakfast cereals and the average portion size is less than 20 grams. As the intake of these food items is rather small, the influence of these cereals could be neglected. Overall, there is not much known about the relation between breakfast habits and the overall nutrient status in European adolescents. Moreover, there are insufficient data on status to be able to draw any conclusions about the nutritional quality of the diets of European adolescents (Lambert *et al*, 2004).

Several authors pronounce the importance of breakfast and that it should be included in educational programmes promoting healthy diets and lifestyles (Gassin, 2001) or even included in school-based nutrition education programmes, involving families, teachers and others to achieve healthier patterns (Aranceta *et al*, 2001). In the UK the Department of Health initiated in schools the breakfast-club schemes. Breakfast-clubs are a form of before-school provision serving food to children who arrive early. The main aims of the scheme were to provide breakfast to children who might otherwise not have eaten, to establish a positive relationship at the start of the school day and to offer children a choice of healthy food, which may help to encourage healthier eating habits. However, a recent study indicates that children who attend breakfast clubs have a poorer nutrient intake than other children at the same schools (Belderson *et al*, 2003). In the meantime, it is shown that parental breakfast consumption is associated with adolescent breakfast eating. This suggests that breakfast programmes that address the whole family or just parents may be more effective (Keski-Rahkonen *et al*, 2003).

The results show that the nutritional profile of Belgian adolescents could be substantially improved by the consumption of a healthful breakfast in a family setting on a daily basis consisting of a variety of foods, namely whole grains products, fruit and (semi-)skimmed milk products or an alternative source of calcium.

4

SOURCES OF SATURATED FATTY ACIDS IN BELGIAN ADOLESCENTS' DIET. IMPLICATIONS FOR THE DEVELOPMENT OF FOOD-BASED DIETARY GUIDELINES

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Abstract

The objectives of the present study are to describe the dietary sources of total fat and of saturated fatty acids (SFA) and to formulate food-based dietary guidelines for SFA in Belgian adolescents. A random sample of 13–18-year-old adolescents was drawn from secondary schools in the region of Ghent. A 7 d estimated food record method was used to quantify nutrient and food intake. The average daily SFA intake is 4% above the recommended 10% of the total energy contribution. The most important contributors of SFA on food group level were 'fats, oils and savoury sauces', 'meat and meat products', 'sugar, confectionery, sweet fillings and sauces', 'cheese', 'milk and milk products' and 'bread, rusk and breakfast rolls'. On food subgroup level 'fresh meat', 'high-fat margarine' and 'high-fat cheese' had the highest contribution to SFA intake in all adolescents. Adolescents with a low SFA intake (lowest tertile) were compared with adolescents with a high intake (highest tertile). In the lowest tertile the intake of total fat and MUFA was significantly lower than in the highest tertile, while the intake of total carbohydrates, mono- and disaccharides and polysaccharides was significantly higher. Overall, the high-fat cheese intake is significantly lower in the lowest tertile, while the fruit intake is higher. The present analysis shows that the nutritional profile of Belgian adolescents could be potentially improved by decreasing the portion sizes of fresh meat (in boys), high-fat margarine, high-fat cheese and reducing intake of commercially prepared baked goods and processed foods, including fast foods.

Introduction

The FAO/WHO report on guidelines for the preparation of food-based dietary guidelines indicated that such guidelines should be based on an existing public health problem and that they should be derived from existing patterns of food intake in the target population rather than from a theoretical basis. Different options were proposed to identify foods that should be included in the guidelines to modify the intake of a specified nutrient. A first option is identifying the foods with high content of the target nutrient. A second option is identifying the major dietary sources of a nutrient. A third option is comparing the food consumption patterns of different population subgroups that achieve a particular nutritional goal (Food and Agricultural Organization / World Health Organization, 1998).

The global strategy on diet, physical activity and health highlights diet and physical activity as the two main risk factors for non-communicable diseases. The same report indicates that recommendations for populations and individuals should include a shift in fat consumption away from saturated fatty acids (SFA) to unsaturated fatty acids (World Health Organisation, 2004). It is well documented that SFA intake raises LDL-cholesterol and is associated with the incidence of CVD, whereas unsaturated fatty acids have the opposite effect (Grundy & Denke, 1990; Hegsted *et al*, 1965; Keys & Parlin, 1966; Kinsell *et al*, 1954). Different classes of SFA can have different effects on plasma lipid and lipoprotein concentrations (Kris-Etherton & Yu, 1997) and, according to some authors, the available evidence on how specific SFA contribute to coronary artery disease is not sufficient to make global recommendations for reducing saturated fats in the diet (German & Dillard, 2004).

However, this issue has been debated in the literature and it does not appear to be important nor feasible to make a distinction between individual SFA in dietary advice to reduce CVD risk, because of the high correlation between the different SFA (Hu *et al*, 1999).

In a previous paper, it has been elucidated that the population distribution of SFA intake is substantially above recommended values (Matthys *et al*, 2003). From a life-course perspective aimed at preventing and controlling non-communicable diseases (World Health Organisation, 2004), it seems desirable to tackle this dietary unbalance early on during childhood and adolescence.

The present study explored existing data on habitual diets of adolescents – the only available Belgian consumption database in young individuals – to formulate food-based dietary guidelines aimed at reducing SFA intake. To the knowledge of the authors, this is the first time that such an attempt has been undertaken in Belgium.

Material and methods

The study was carried out in Ghent, a city in the Dutch-speaking part of Belgium, between March and May 1997. The study sample consisted of 656 adolescents (age 13–18 years) randomly selected on the basis of a multistage cluster sampling technique. The design and methodology have been described in more detail elsewhere (Matthys *et al*, 2003). In brief, local private and public secondary schools (n=5) were randomly selected. All contacted schools agreed to participate. Different educational options – classical education and vocational training – were represented in the sample. Within each school, classes were selected in such a way that a uniform distribution over the age range 13–18 years was obtained. Of the 656 adolescents, 565 were considered eligible. Non-eligible students (n=91) were on sickness leave or had moved to other schools. Of these 565 eligible students, 411 (72.7 %) actually participated. Because of missing data, the food diaries of seventy students were rejected. Hence, results are reported for 341 of the 565 eligible students (60.3 %). Results are given separately for boys (n=129) and girls (n=212). A detailed description of the characteristics of the study population is published elsewhere (Matthys *et al*, 2003).

A 7 d estimated food record method (semi-structured diary) was used to quantify food and nutrient intake. Information on the type (including brand names) and amount of food consumed was collected through an open-entry format. Instructions for the completion of the diary and regular checks for quality and completeness of the diaries were carried out by experienced dieticians.

The storage of data on intake of individual food items was detailed and contained altogether 745 different food items. From these 745 food entries, 527 were identified as fat containing and were further used in the present study. Dishes were broken down into their constituent ingredients under the condition that all the ingredients were known and described. Sometimes dishes were not broken down into their ingredients, because the composition was not known. Decisions regarding the grouping of foods and the disaggregating of dishes were based on the judgement of the investigators. The dishes were mostly disaggregated to a level at which foods would easily be classified into food groups of the Flemish version of the food pyramid (Vlaams Instituut voor Gezondheidspromotie, 2003).

Nutrient composition data used in the present study are those from the Belgian and the Dutch food composition tables (NEVO, 1993; NUBEL, 1992; NUBEL, 1995). Average nutrient and food intakes were calculated as the mean of the 7 d intake period.

Under-reporting was studied using the cut-offs provided by Goldberg *et al*. (1991). On the basis of the Goldberg formula, an average study-specific energy intake/BMR ratio of 1.1 was calculated as the minimal acceptable value at the individual level.

In the present study, three main objectives could be distinguished. A first objective of the study was to describe the food sources of total fat and SFA. The mean proportion of a nutrient from a food item is determined by calculating the proportion of that nutrient from that food item for each individual and then by taking an arithmetic mean of all the proportions. This mean proportion methodology is described elsewhere (Krebs-Smith *et al*, 1989). Food items were classified in different food groups (n=22) according to the Dutch food composition table (NEVO, 2001). A total of ten groups had a very low contribution to the total fat intake and were aggregated in one group, namely ‘other’. The groups classified under ‘other’ were ‘potatoes’, ‘alcoholic and other beverages’, ‘cereal products (e.g., pasta, rice) and binding agents (e.g., bread crumbs)’, ‘savoury sandwich fillings (e.g., peanut butter)’, ‘herbs and spices’, ‘vegetables’, ‘fruit’, ‘legumes’, ‘soya products and meat substitutes' and 'soup'. On the other hand, a few groups (n=5) were disaggregated in subgroups. The group 'fats, oils and savoury sauces' was divided into 'high-fat margarine' (≥60 g fat per 100 g margarine), 'butter', 'oil' and 'low-fat margarine' (<60 g fat per 100 g margarine). The groups 'meat' and 'fish' were divided into a subgroup 'fresh' and a subgroup 'processed'. In the group of 'cheese', 'high-fat cheeses' (>30 g fat per 100 g cheese) were distinguished. The group 'sugar, confectionery, sweet fillings and sauces' was divided into 'confectionery' (e.g., candy bars) and 'sweet fillings and sauces' (e.g., chocolate). The food group 'bread, rusk and breakfast rolls' was divided into 'bread', 'rusk' and 'breakfast rolls' (e.g., croissants).

The second objective of the present study was the identification of dietary habits adopted by groups who have high and low intakes of SFA (Food and Agricultural Organization / World Health Organization, 1998). Therefore subjects were classified into tertiles. The average population intake of energy and nutrients and the average consumption of different foods were calculated in all tertiles. Also, for the various foods, the percentage of consumers was calculated.

In a third phase of the present paper, simulation scenarios were conducted to explore the effect of changes in food consumption in order to decrease the SFA intake. Three kinds of scenarios were distinguished. In a first scenario, all high-fat cheese was substituted by low-fat cheese in all adolescents. In the second scenario, high-fat margarines were substituted by low-fat margarines. The third scenario was a combination of the first and second scenarios.

Statistical analysis was done with the SPSS software version 12 (SPSS Inc., Chicago, IL, USA). A Kolmogorov–Smirnov test was used to test for normality. Non-parametric tests (Mann–Whitney U test) were used to determine differences between the lowest and highest tertile of the population in nutrient and food intake. To identify the food groups' contribution to the variability in SFA intake (g/d) a stepwise multiple regression, where the SFA intake is the dependent variable and intakes of food groups are the independent variables, was used. These analyses were completed by correlation analyses (Spearman) to identify key food groups for food-based dietary guidelines (Leclercq & Arcella, 2001). Given the multitude of statistical tests, a P value of < 0.01 was taken in order to reduce the probability of false-positive findings.

The present study was approved by the ethical committee of the Ghent University Hospital.

Results

Energy intake, energy from total fat and from the fat sub-fractions is given by sex in Table 4.1. Mean energy intake was respectively 11108 kJ for boys and 8248 kJ for girls. The overall picture of energy contribution from the different fat fractions is very similar in boys and girls. Both boys and girls have a total fat intake that is above the recommended intake of 30% energy as fat. The mean SFA intake, 14.5% energy, is above the upper limit of 10% energy. The mean intake of MUFA and total PUFA fell within the range of the recommended intake.

Table 4.1: Distribution parameters of energy intake (kJ), intake of total fat and different sub-fractions (E%*) in adolescents according to gender, plus Belgian Nutritional Recommendations

	Boys (n=129)	Girls (n=212)	Dietary guidelines for Belgium
	Median (25th – 75th percentile)	Median (25th – 75th percentile)	
Energy	10911 (9480-12658)	8226 (6918-9383)	Age dependent
Total fat	36.5 (32.9-39.2)	35.7 (31.9-38.8)	< 30
SFA	14.7 (13.0-16.3)	14.27 (12.8-16.0)	< 10 intake not necessary
MUFA	13.6 (12.2-15.0)	13.1 (11.7-15.2)	> 10
PUFA	5.6 (4.5-7.1)	5.5 (4.6-6.4)	5.3 – 10

* E%: energy percentage
SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids

In Tables 4.2 and 4.3 the proportional contribution of different food groups to total fat and SFA are shown. The major contributors to total fat intake are ‘fats, oils and savoury sauces’, ‘meat and meat products’, ‘sugar, confectionery, sweet fillings and sauces’, ‘bread, rusk and breakfast rolls’ and ‘cheese’, although the rank order was slightly different between boys and girls. ‘Fresh meat’ and ‘high-fat margarine’ together, account for about 20% of the total fat intake.

Table 4.2: Median intake (g/day), percentage consumers of different food groups and proportional contribution of food groups to total fat and SFA for adolescent boys (n = 129)

	Median intake	Percentage consumers	Food sources (%) for Total fat: Median (25^{th} – 75^{th} Percentile)	Food sources (%) for SFA: Median (25^{th} – 75^{th} Percentile)
Fats, oils & savoury sauces	45.7	100	28.5 (20.2 - 34.8)	20.9 (15.2 - 29.4)
High-fat margarine	*10.3*	*99*	*8.2 (3.9 - 14.2)*	*8.9 (4.6 - 14.5)*
Oils	*3.4*	*76*	*2.6 (0.2 - 5.8)*	*1.0 (0.1 - 2.8)*
Butter	*0.0*	*32*	*0.0 (0.0 - 1.4)*	*0.0 (0.0 - 2.2)*
Low-fat margarine	*0.0*	*33*	*0.0 (0.0 - 2.5)*	*0.0 (0.00 - 1.78)*
Meat & Meat products	140.6	100	18.7 (12.9 - 25.3)	19.8 (13.4 - 25.5)
Meat (fresh)	*93.6*	*99*	*11.3 (7.0 - 14.8)*	*11.6 (7.4 - 15.9)*
Processed meat	*45.7*	*95*	*7.3 (3.2 - 11.5)*	*7.3 (3.1 - 12.4)*
Sugar, confectionary, sweet fillings & sweet sauces	26.1	95	7.6 (3.9 - 14.1)	8.0 (3.8 - 14.5)
Sweet fillings & sauces	*18.9*	*92*	*5.8 (2.4 - 10.3)*	*6.1 (2.6 - 11.0)*
Confectionery	*2.9*	*56*	*0.5 (0.0 - 2.8)*	*0.6 (0.0 - 3.8)*
Bread, rusk & breakfast rolls	188.6	100	7.3 (5.3 - 10.1)	6.7 (4.2 - 10.1)
Cheese	18.4	92	5.7 (2.1 - 11.6)	7.9 (3.3 - 17.0)
High-fat cheese	*16.0*	*88*	*5.0 (1.6 - 10.8)*	*6.9 (2.2 - 14.3)*
Milk & milk products	234.3	98	5.9 (2.5 - 9.4)	9.6 (4.2 - 14.3)
Cakes & biscuits	31.4	90	5.8 (2.1 - 9.5)	7.5 (2.4 - 11.5)
Nuts, seeds & snacks	11.4	75	2.6 (0.2 - 6.9)	1.8 (0.1 - 4.5)
Composite dishes	17.1	52	1.0 (0.0 - 4.9)	0.8 (0.0 - 4.1)
Poultry	21.4	77	1.1 (0.2 - 2.5)	0.8 (0.1 - 1.9)
Fish & fish products	14.3	64	0.3 (0.0 - 1.3)	0.2 (0.0 - 1.0)
Fish (fresh)	*2.1*	*50*	*0.0 (0.0 - 0.6)*	*0.0 (0.0 - 0.4)*
Processed fish	*0.0*	*33*	*0.0 (0.0 - 0.4)*	*0.0 (0.0 - 0.3)*
Eggs	6.3	62	0.7 (0.0 - 1.6)	0.4 (0.0 - 1.1)
Other	111.8	100	1.2 (0.5 - 2.6)	0.7 (0.3 - 1.4)

In boys, the five most important contributors of SFA are ‘fats, oils and savoury sauces’, ‘meat and meat products’, ‘sugar, confectionery, sweet fillings and sauces’, ‘cheese’ and ‘milk and milk products’. In girls, the major contributors for SFA are ‘fats, oils and savoury sauces’, ‘meat and meat products’, ‘cheese’, ‘milk and milk products’ and ‘bread, rusk and breakfast rolls’. ‘Fresh meat’, ‘high-fat margarine’ and ‘high-fat cheese’ are the subgroups with the highest contribution to SFA intake in both boys and girls. ‘High-fat cheese’ is the most important source of SFA in girls.

Table 4.3: Median intake (g/day), percentage consumers of different food groups and proportional contribution of food groups to total fat and SFA for adolescent girls (n = 212)

	Median intake	Percentage consumers	Food sources (%) for Total fat Median (25th – 75th Percentile)	Food sources (%) for SFA Median (25th – 75th Percentile)
Fats, oils & savoury sauces	31.1	100	26.8 (18.8 - 33.6)	19.1 (13.7 - 26.1)
High-fat margarine	*6.6*	*99*	*7.6 (4.7 - 13.3)*	*7.9 (4.4 - 13.9)*
Oils	*2.1*	*75*	*2.4 (0.0 - 5.1)*	*0.9 (0.0 - 2.3)*
Low-fat margarine	*0.0*	*43*	*0.0 (0.0 - 3.0)*	*0.0 (0.0 - 1.5)*
Butter	*0.0*	*23*	*0.0 (0.0 - 0.0)*	*0.0 (0.0 - 0.0)*
Meat & Meat products	87.1	99	15.0 (10.0 - 21.5)	14.6 (9.0 - 21.8)
Meat (fresh)	*60.0*	*95*	*8.9 (5.5 - 14.3)*	*8.8 (5.3 - 14.4)*
Processed meat	*25.0*	*90*	*5.4 (2.2 - 9.4)*	*5.1 (2.1 - 8.2)*
Cheese	21.7	93	8.6 (4.2 - 16.1)	12.3 (5.8 - 22.3)
High-fat cheese	*15.6*	*91*	*7.2 (2.4 - 14.9)*	*10.2 (3.6 - 19.8)*
Bread, rusk & breakfast rolls	140.3	99	8.2 (6.0 - 11.2)	7.8 (5.0 - 11.2)
Sugar, confectionary, sweet fillings & sweet sauces	19.4	95	8.0 (4.3 - 12.2)	8.6 (4.1 - 13.5)
Sweet fillings & sauces	*12.1*	*91*	*5.3 (2.1 - 9.4)*	*5.5 (2.4 - 9.3)*
Confectionery	*5.0*	*62*	*1.3 (0.0 - 3.5)*	*1.6 (0.0 - 4.6)*
Cakes & biscuits	24.5	91	5.9 (2.9 - 10.8)	7.8 (3.2 - 13.1)
Milk & milk products	165.9	96	6.0 (2.8 - 11.5)	9.3 (4.5 - 17.8)
Nuts, seeds & snacks	8.0	70	2.8 (0.0 - 5.7)	2.0 (0.0 - 4.6)
Composite dishes	0.0	44	0.0 (0.0 - 3.0)	0.0 (0.0 - 2.0)
Poultry	17.9	68	1.1 (0.0 - 2.7)	0.8 (0.0 - 1.8)
Eggs	5.6	72	0.8 (0.0 - 1.9)	0.5 (0.0 - 1.4)
Fish & fish products	8.6	65	0.3 (0.0 - 1.0)	0.2 (0.0 - 0.7)
Fish (fresh)	*0.0*	*46*	*0.0 (0.0 - 0.6)*	*0.0 (0.0 - 0.3)*
Processed fish	*0.0*	*36*	*0.0 (0.0 - 0.2)*	*0.0 (0.0 - 0.2)*
Other	90.6	98	1.4 (0.5 - 3.5)	0.7 (0.3 - 1.9)

The individual proportional contributions varied greatly in all food (sub)groups. In boys, the proportional contribution of ‘cheese’ to SFA intake of subjects of the highest tertile is higher than of subjects in the lowest tertile, although not significantly (P=0.025). In girls, the proportional contribution of ‘meat and meat products’ and ‘high-fat cheese’ is higher in the highest tertile and borderline significant (meat P=0.029; high-fat cheese P=0.012) (data not shown).

In Tables 4.4 and 4.5 daily intake of some selected nutrients and food groups in adolescents according to tertiles of SFA (in energy %) are given. Energy intake and the overall EI/BMR ratio did not differ significantly between tertiles in boys and girls. The percentage of subjects with a ratio below the individual cut-off point of 1.1 was not significantly different between tertiles. Nevertheless, the percentage was low in boys but about 20% in girls.

In both boys and girls in the lowest tertile the intakes of total fat, SFA, MUFA and the food group 'cheese' are significantly lower than in the highest tertile, while the intakes of total carbohydrates, mono- and disaccharides and polysaccharides are significantly higher. The percentage of consumers of 'cheese' is lower in the lowest tertile in both boys and girls.

In boys, the Ca intake in the lowest tertile is significantly lower than in the highest tertile. Female subjects of the highest tertile have a statistically significant higher intake of 'meat and meat products' and a statistically significant lower intake of 'fruit'.

Although the differences were not statistically significant the consumption of 'fresh meat' in boys of the lowest tertile (84.8 g) was lower than the intake of boys of the opposite tertile (106.8 g) (P=0.014). In girls, both the intakes of 'fresh meat' and 'processed meat' were statistically significant lower in the lowest tertile.

A similar intake pattern was found for 'high-fat margarine'. Boys of the lowest tertile (12.0 g) had a lower intake than boys of the highest tertile (15.4 g) (P=0.102). Girls of the lowest tertile (6.9 g) had a significant lower intake than their counterparts (11.4 g) (P<0.000).

Girls from the lowest tertile have a higher intake of 'bread' (131.4 g vs. 114.9 g; P=0·041) and a lower intake of 'breakfast rolls' (17.0 g vs. 28.3 g; P=0·027) than their upper tertile counterparts. Analyses based on consumers only did not differ from the overall analyses (data not shown).

Table 4.4: Daily intake of nutrients and food groups in male adolescents (n=129), according to tertiles of energy intake from SFA

	Intake of SFA according to tertile						
	Tertile 1 (n=43)		Tertile 2 (n=43)		Tertile 3 (n=43)		P-value
	Median	Percentage consumers	Median	Percentage consumers	Median	Percentage consumers	
Age (years)	15.0		15.0		15.0		0.775
Energy (kJ)	10915		10634		11166		0.150
EI/BMR	1.5		1.6		1.6		0.098
EI/BMR < 1.1 (%)	7.0		9.3		7.0		0.905
Total fat	32.0		36.8		39.6		0.000
SFA	12.2		14.7		17.1		<0.001
MUFA	12.3		14.3		14.4		<0.001
PUFA	5.3		5.6		5.6		0.935
Protein	14.3		14.2		14.3		0.726
Total Carbohydrates	52.7		49.2		45.4		<0.001
Mono- & disaccharides	25.1		23.2		20.1		<0.001
Polysaccharides	24.7		22.8		21.5		0.004
Calcium	718.3		869.4		997.6		0.009
Iron	13.7		12.8		13.3		0.422
Vitamin C	82.0		71.9		62.4		0.098
Potatoes	150.0	100	117.9	100	136.7	100	0.969
Bread, rusk & breakfast rolls	210.9	100	191.4	100	172.9	100	0.427
Egg	6.3	67	4.2	56	7.1	67	0.951
Fruit	74.9	91	51.1	91	73.9	95	0.969
Cakes & biscuits	27.9	86	27.1	93	45.6	91	0.150
Poultry	21.4	65	22.9	79	22.9	86	0.105
Cereal products & binding agents	53.6	98	39.6	95	58.6	98	0.941
Vegetables	116.1	100	109.0	100	119.2	100	0.955
Savoury sandwich fillings	0.0	23	0.0	26	0.0	14	0.242
Cheese	12.1	84	17.0	93	36.4	98	<0.001
Milk & milk products	207.7	100	268.9	98	226.7	98	0.390
Nuts, seeds & snacks	11.4	74	15.7	81	6.4	70	0.285
Sugar, confectionary, sweet fillings & sweet sauces	39.0	98	33.9	100	35.7	100	0.829
Fats, oils & savoury sauces	39.2	100	56.7	100	47.5	100	0.072
Fish & fish products	17.9	74	12.5	63	7.1	54	0.033
Meat & Meat products	135.7	100	138.9	100	159.3	100	0.070

Macronutrient intake is given in energy percentage, micronutriënt intake is given in mg/day and food intake is given in g/day.

Table 4.5: Daily intake of nutrients and food groups in female adolescents (n=212), according to tertiles of energy intake from SFA

	Intake of SFA according to tertile						
	Tertile 1 (n=70)		Tertile 2 (n=71)		Tertile 3 (n=71)		P-value
	Median	Percentage consumers	Median	% consumers	Median	Percentage consumers	
Age (years)	16.0		16.0		16.0		0.319
Energy (kJ)	8047		8152		8528		0.064
EI/BMR	1.3		1.4		1.4		0.051
EI/BMR < 1.1 (%)	22.9		19.7		18.3		0.850
Total fat	31.3		35.3		39.3		<0.001
SFA	12.3		14.2		16.8		<0.001
MUFA	11.9		13.1		14.9		<0.001
PUFA	5.3		5.6		5.7		0.193
Protein	14.7		14.9		14.8		0.088
Total Carbohydrates	53.7		49.3		45.6		<0.001
Mono- & disaccharides	25.1		23.3		20.1		<0.001
Polysaccharides	25.6		22.6		21.7		<0.001
Calcium	695.3		764.3		773.9		0.042
Iron	9.7		9.9		10.2		0.625
Vitamin C	80.3		67.4		59.8		0.016
Potatoes	93.0	99	91.1	99	96.4	100	0.366
Bread, rusk & breakfast rolls	156.5	99	137.1	100	135.7	100	0.194
Egg	6.9	79	2.9	63	6.4	75	0.540
Fruit	111.8	96	81.4	93	75.0	96	0.009
Cakes & biscuits	27.9	87	23.3	92	22.9	94	0.924
Poultry	17.86	67	17.4	61	23.2	72	0.498
Cereal products & binding agents	48.8	99	34.3	89	33.6	94	0.086
Vegetables	98.6	100	89.3	100	100.4	100	0.343
Savoury sandwich fillings	0.0	26	0.0	31	0.0	18	0.348
Cheese	12.9	91	22.2	94	30.5	94	<0.001
Milk & milk products	169.6	94	165.7	96	160.0	97	0.853
Nuts, seeds & snacks	7.9	73	8.6	69	8.6	68	0.580
Sugar, confectionary, sweet fillings & sweet sauces	24.4	100	27.7	99	27.9	100	0.215
Fats, oils & savoury sauces	31.3	100	29.4	100	37.6	100	0.116
Fish & fish products	6.8	61	13.6	69	7.1	63	0.924
Meat & Meat products	63.4	97	90.0	99	108.4	100	<0.001

Macronutrient intake is given in energy percentage, micronutriënt intake is given in mg/day and food intake is given in g/day.

Stepwise multiple regression analyses (data not shown) were used in boys and girls separately to identify the food groups that determine SFA intake. In boys, the food groups (in order of importance) 'cheese', 'fats, oils and savoury sauces', 'cakes and biscuits', 'milk and milk products', 'sugar, confectionery, sweet fillings and sauces' and 'meat and meat products' were found to be responsible for 64% of the variability in the SFA intake. In girls, the food groups (in order of importance) 'sugar, confectionery, sweet fillings and sauces', 'meat and meat products', 'cheese', 'cakes and biscuits', 'fats, oils and savoury sauces' and 'milk and milk products' were found to be responsible for 73% of the variability in the SFA intake. In both boys and girls the highest correlation with SFA, which varied between 0.23 and 0.49 in boys and between 0.35 and 0.44 in girls, was found for the food groups 'sugar, confectionery, sweet fillings and sauces', 'meat and meat products', 'cheese', 'cakes and biscuits' and 'fats, oils and savoury sauces'. Non-significant, weak positive correlations were found for intakes of 'fruit' (r=0.08 for boys; r=0.04 for girls) and 'vegetables' (r=0.03 for boys; r=0.14 for girls) and a weak negative correlation of 'fish' (r= - 0.08 for boys; r= - 0.03 for girls) with SFA intake was found.

In Figure 4.1, simulation scenarios that explored the effect of food changes in respect to decreasing the SFA intake are shown. In a first simulation scenario, substitution of all high-fat cheese by low-fat cheese, the energy contribution of total fat decreased with 1 energy % in boys and with 1.5 energy % in girls. The decrease in the contribution of SFA was respectively 0.7 energy % in boys and 1 energy % in girls. The decrease in MUFA intake was 0.4 energy % in boys and 0.6 energy % in girls. No differences were observed in PUFA intake. When the different tertiles were compared, we found that the decrease of SFA in the highest tertile was bigger than in the lowest tertile in both boys and girls. Ca intake remained similar.

In a second simulation scenario, substitution of all high-fat margarines by low-fat margarine, the energy contribution of total fat decreased with 1.3 energy % in boys and with 1.1 energy % in girls. The decrease in the contribution of SFA was respectively 0.9 energy % in boys and 0.8 energy % in girls. The decrease in MUFA intake was 0.1 energy % in both boys and girls. A decrease of 0.3 energy % of PUFA was observed in all adolescents.

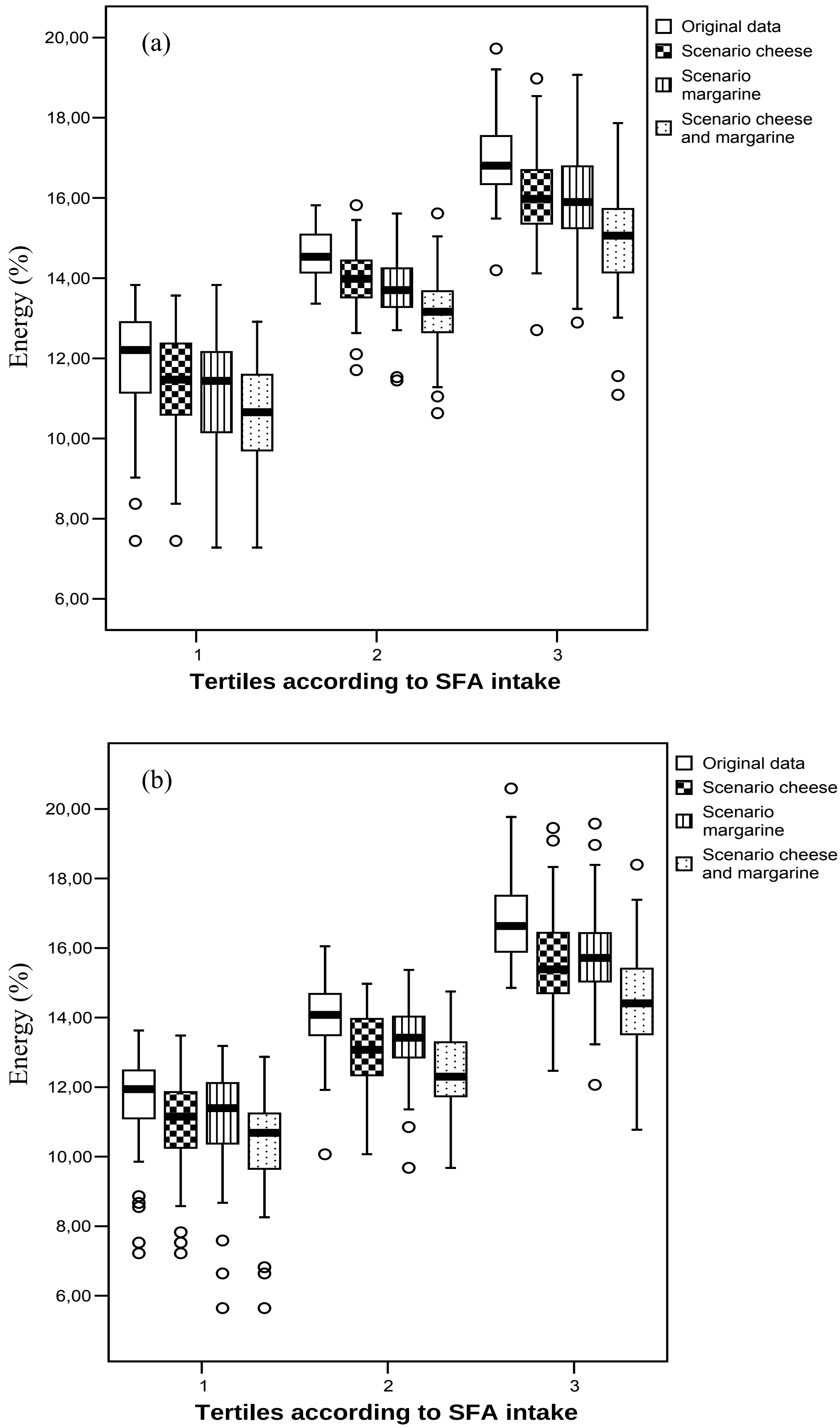

Figure 4.1: Box and Whisker plot of the SFA intake (energy %) in different scenarios according to SFA intake tertiles in boys (a) and girls (b).

In the third simulation scenario, combination of the first and the second scenario, the energy contribution of total fat decreased with 2.3 energy % in boys and with 2.6 energy % in girls. The decrease in the contribution of SFA was respectively 1.6 energy % in boys and 1.7 energy % in girls. The decrease in MUFA intake was 0.5 energy % in boys and 0.7 energy % in girls. A decrease in PUFA intake of 0.3 energy % was found.

In all three scenarios, we found that the decrease of SFA in the highest tertile was greater than in the lowest tertile, in both boys and girls. However, the decreases were rather small (in absolute figures) between the simulation scenarios; they were all significantly different ($P<0.001$).

Discussion

SFA have the capacity to raise serum cholesterol (Keys & Parlin, 1966). Investigations have shown that lauric, myristic and palmitic acid raise both LDL- and HDL-cholesterol; thus the LDL/HDL ratio increases (Katan *et al*, 1994). Epidemiological studies provide evidence in support of the hypothesis that a higher dietary intake of saturated fat is associated with an increased risk of coronary disease but results from different studies are rather inconsistent (Hu *et al*, 1997; Kromhout *et al*, 1995). Epidemiological research has estimated that a 1% decrease in serum cholesterol leads to a 2% reduction in coronary events (1984). In a previous publication, the intake of SFA in Flemish adolescents was identified as one of the major nutritional concerns and an important factor to tackle from a public health point of view. The mean SFA intake was found to be 14.6% in boys and 14.4% in girls of the total energy intake. There are only 3.9% of the boys and 2.6% of the girls who have an average SFA intake below the recommended value of 10 %. The high intake of SFA in adolescents forms the rationale to develop new food-based dietary guidelines to modify the current intake. The FAO/WHO report on guidelines for the preparation of food-based dietary guidelines mentioned different options to identify foods to be included in these guidelines (Food and Agricultural Organization / World Health Organization, 1998). The first option as described was not performed. In the present study, the first objective was to determine the main dietary sources. The major contributors – on food-group level – for

SFA in all adolescents are ‘fats, oils and savoury sauces’, ‘meat and meat products’, ‘sugar, confectionery, sweet fillings and sauces’, ‘cheese’, ‘milk and milk products’ and ‘bread, rusk and breakfast rolls’. On food-subgroup level, ‘fresh meat’, ‘high-fat margarine’ and ‘high-fat cheese’ are the items with the highest contribution to SFA intake in both boys and girls. The total population intakes and the consumers-only intakes of the latter food items were higher in the highest tertile. Those tertiles have a significantly higher proportional contribution of ‘high-fat cheese’. ‘Fruit’ intake was significantly lower among high SFA consumers, only for girls. The stepwise multiple regression analyses confirmed these findings in boys. ‘Cheese’ explained the highest proportion of inter-individual variability in SFA intake in boys. In girls, the food group ‘sugar, confectionery, sweet fillings and sauces’ (including candy bars) was the most important contributor of the variability in SFA intake and had the highest correlation with SFA intake.

In using this food consumption database to examine patterns of food and nutrient intake among adolescents for the purpose of developing food-based dietary guidelines, it is important to consider some methodological issues. The database for this analysis dated from 1997. This may not be the most accurate reflection of the current pattern of nutrient and food intakes among adolescents but is the most representative survey. This may be particularly true of certain food items which have changed in availability or in composition in the last few years (for example, high-fat margarine, yoghurts) (Flynn & Kearney, 1999). In addition, the study was conducted during spring; therefore it is not possible to take into account seasonal effects. Under-reporting can influence the usefulness of dietary data as a basis of food-based dietary guidelines (Becker & Welten, 2001). However, in the present study there were no significant differences in the percentage of under-reporters between tertiles, nor significant differences in the mean EI/BMR ratio of each tertile. Thus, it can be assumed that in the present study the effect of under-reporting is negligible, although a selective way of under-reporting food items between tertiles cannot be fully excluded (Becker *et al*, 1999). The issue of food composition tables in the development of food-based dietary guidelines cannot be neglected. The choice of food composition database may introduce a major source of error due to incompleteness, seasonal variation and may have a great contribution towards the lack of agreement between different assessment tools. In the present study, the food composition databases were locally developed (Belgium and the Netherlands); therefore comparisons with other European countries could introduce errors (Leclercq *et al*, 2001). The issue of survey duration should be considered in the development of food-based dietary guidelines (Lambe & Kearney, 1999). The present survey duration was 7 d, which is in general accepted as a representation of the current 'usual' intake (Nelson & Bingham, 1996). Nelson *et al*. (1989) have pointed out that to classify subjects in their true thirds, fourths, fifths, etc, of the SFA distribution intake respectively 7 d (male adults) and 6 d (female adults) are needed. To estimate true average SFA intake for an individual, longer periods are necessary with estimates in the literature from 30 to 156 d for adult men and from 32 to 114 d for adult women (Basiotis *et al*, 1987). However, for the purpose of estimating group means a substantially smaller number of days is required. In order to estimate true average SFA intake accurately for a group of male adults (n=13), a number of 8 d and for a group of female adults (n=16) a number of 7 d has been reported in the past (Basiotis *et al*, 1987). However, to the authors' knowledge, no specific figures on this topic are available for adolescents, nor are specific data available on the number of days necessary to estimate intake of food items or food groups. On the basis of the above, the authors conclude that the instrument used in the present study allows valid comparisons between groups of individuals (tertiles) and tackles the issue of survey duration proposed by Lambe & Kearney (1999). However, due to the lack of comparable, validated food composition database and the unavailability of a valid indicator to detect adolescent under-reporters (Black, 2000), it remains difficult to predict the total impact of all these factors on the development of food-based dietary guidelines.

One of the limitations of the methodology used in the present study is the way of classifying the dishes. The standard procedure was to break down a dish into different ingredients; however, this method was not always possible. Practically this means that the same food items were classified in different ways. For example, 'spaghetti bolognaise' was broken down into spaghetti, tomatoes, etc when the composition was known. In other circumstances the composition was not known (for example, eaten at restaurant) and was not broken down into its different components. The storage of the data does not allow us to see what the effect is of classifying in different ways. On one hand the current methodology does not allow us to ascertain the importance of dishes as a source of nutrient but on the other hand it has been reported that the disaggregation of dishes gave a more precise picture of the dietary contributions of various food groups (Krebs-Smith *et al*, 1990).

The major dietary sources of saturated fat have a different ranking order in boys compared with girls. These differences in the ranking order could be explained by the differences in the amount consumed of a certain food group in relation to the SFA content. A comparison of the present results with other studies is difficult to make and need to be interpreted carefully, mainly because of potential differences in methodology (ways of grouping foods, mean proportion v. population proportion, disaggregating dishes) and study population. In an older Belgian study among adults (n=10694; aged 25–74 years; between 1980 and 1985), the mean SFA intake was 17.5 energy % and the main dietary sources of SFA were butter (23.9 %), meat and meat products (25 %), all margarines (12 %), cheese (10 %) and whole milk (5.1 %) (Staessen *et al*, 1998). A similar pattern is shown in the present study; however, the contribution of butter is decreased in favour of margarines. In an American study in adolescents (n=100; average age 15 years; in 1984), saturated fat accounted for more than 12% of energy. Dairy; meat, fish, poultry and eggs, and bakery products were the primary sources of SFA intake in American adolescents (Witschi *et al*, 1990). In another US adolescent setting (n=1426; aged 12–18 years; between 1989 and 1991), milk (17.5 %), cheese (13.8 %), beef (11.7 %) and cake and biscuits (5.3 %) were the main dietary SFA sources (Subar *et al*, 1998). In Spanish children (n=1112; aged 6–7 years; in 1998–9) the SFA contribution to the total energy was on average 16.7 %. The principal source of SFA was whole milk (14.9 %), followed by ham (8.2 %), olive oil (6.7 %), dried fruits and nuts (6.4 %) and red meat (5.7 %) (Royo-Bordonada *et al*, 2003). The current SFA intake in adolescents is lower than previously found in Belgian adults and in Spanish children but higher than in American adolescents. The current food sources of SFA were comparable with other studies although milk contributed to a lesser extent than in other countries.

The significant higher intake of fruit in the lowest tertile of female adolescents, combined with the negative association of fish consumption and SFA intake, could suggest that an increase of the intake of fish and fruit could lower the intake of SFA. However, the weak correlation of fruit and vegetables with SFA intake indicates that the assumption that lowering saturated fat intake will change other relevant dietary intake variables in a favourable way is not necessarily legitimate. Therefore, when one develops food-based dietary guidelines, it is recommended to restrict the number of dietary goals, preferably just one (Lowik *et al*, 1999).

Overall, the consumption of ‘sugar, confectionery, sweet fillings and sauces’ (recommendation as low as possible) and ‘meat and meat products’ (recommendation 100 g/d) (boys) is high and the consumption of ‘fruit’ (recommendation 250 g/d) and ‘vegetables’ (recommendation at least 300 g/d) is too low in all tertiles (Vlaams Instituut voor Gezondheidspromotie, 2003). In boys and girls, the intake of ‘fruit’ is lower in the highest tertile and the intake of ‘meat and meat products’ and ‘cheese’ is higher. The consumption of ‘breakfast rolls’ (rich in SFA) was higher in highest tertiles. The proportional contribution of SFA to the total fat intake is in subjects of the highest tertile higher than in subjects of the lowest tertile. The intake of Ca is higher in the former while the intake of vitamin C is higher in the latter. Analogous results were found in adults in the UK (Wearne & Day, 1999).

Different options to change the intake of a specific nutrient have been suggested (Gibney, 1999a). In the current context, the used strategy explores whether, within a given food category, nutrient intake can be changed by switching to a comparable alternative. The authors would like to underline the importance of the other options mentioned by Gibney (1999 a,b), but explore the effects of changing high-fat margarine to low-fat margarine and high-fat cheese to low-fat cheese. The rationale to choose high-fat margarine and high-fat cheese was based on their high proportional contribution to the total SFA intake. The current simulation had several limitations and was based on highly conservative assumptions. It was suggested that all adolescents will change to the proposed alternative. No changes in percentage consumers, portion size and frequency were taken into account. The effect of introducing an alternative on taste or food preference or cooking processes was ignored. The so-called hidden SFA (for example, biscuits) were not taken into account. The energy intake did not remain the same, which is in conflict with the general staring point of preparing food-based dietary guidelines, namely energy balance. However, the simulation showed that the intake of SFA decreased significantly by introducing alternative foods. The effect was bigger in the highest tertiles; this is due to the higher consumed amounts of the replaced foods. However, the proportional contribution of all macronutrients to total energy intake changed. The current simulation shows that it is not possible – on population level – to decrease SFA intake below the upper limit only by switching to an alternative food. However, a combination of different strategies such as decreasing the portion sizes of high-fat cheese and meat and meat products, lowering the proportion of specific food categories and changing the frequency of food groups will be needed.

Based on the present findings one could suggest that efforts to decrease the level of consumption of fresh meat (in boys), high-fat margarine and high-fat cheese should be a priority to lower the SFA intake. Another alternative would be to choose lean alternatives. In girls, attention has to be paid on food items belonging to the sugar, confectionery, sweet fillings and sauces food group. At the same time an increase of the consumption of fruit and vegetables could be introduced. Before these issues could be used as a basis for food-based dietary guidelines to decrease the intake of SFA among adolescents, it is advisable to carry out qualitative research in selected focus groups in order to identify the best strategy (Food and Agricultural Organization / World Health Organization, 1998; Gibney, 1999a). There are a number of factors that should also be considered before implementing food-based dietary guidelines; namely, practicality, comprehensibility and cultural acceptability (Food and Agricultural Organization / World Health Organization, 1998).

A possible nutritional consequence of implementing the abovementioned guidelines is that the total fat content decreases where fat is needed as a vehicle for fat-soluble vitamins. At the same time, a decrease of, for example, the portion size of high-fat cheese could decrease the intake of Ca as it is already low in the present study. Another option would be to choose cheese with reduced fat content (if available), which also contains as much or more Ca. A change in the intake of one nutrient introduces a change in the intake of another (e.g., Ca, vitamin A, D).

Individuals who choose to change their dietary pattern in favour of a lower SFA intake probably reduce the intake of all fatty acid categories (Gibney, 1999b). The only way this can be prevented is by changing the fatty acid composition of the fats within these food categories. Therefore by developing guidelines, an effective partnership and collaboration among the many sectors (governments, food industry and health professionals) that influence food supply and food selection is recommended (Anderson & Zlotkin, 2000).

To the knowledge of the authors, this is the first comprehensive examination of food sources of SFA in Belgian adolescents. The results show that the nutritional profile of Belgian adolescents could be substantially improved by decreasing the portion sizes of fresh meat (in boys), high-fat margarine and high-fat cheese, by choosing vegetable oils and by reducing intake of commercially prepared baked goods, snack foods, and processed foods, including fast foods. Another option would be to choose lean alternatives, if available.

5

ADOLESCENTS' EDUCATION AND THEIR DIET RECORDED BY 7-DAY FOOD RECORDS

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Abstract

Objective: This study investigated associations between dietary habits and socio-economic status in adolescents.

Methods: A random sample of adolescents (13-18y) participated in a dietary survey using a 7-day estimated dietary record. Respondents' educational training (general/vocational) and parental education (low/medium/high) were used as indicators of socio-economic status.

Results: In girls, the prevalence of overweight is higher when following vocational training or having a low parental education. In girls, the energy and micronutrient intake was higher in respondents with a general training and in those with a high parental education. Girls following a general training have significantly higher intake of fruit, vegetables, breakfast cereals, cheese and milk & milk products, while their intake is significantly lower for soft drinks. Girls with a high parental education have a higher intake of cake & biscuits and milk & milk products.

In boys, small differences in micronutrient and food intake were found between different educational levels.

In both sexes, the diet of general trained adolescents was more varied.

Conclusion: The results demonstrate trends which highlight the need for continued efforts to improve the adolescents' diet, particularly in lower social groups.

Introduction

Differences in educational training underlie many health disparities. Inequalities in education are associated not only with diverging patterns in mortality and morbidity (Mackenbach *et al*, 2000) but also with the main determinants of health, such as the quality of the environment and health-related behaviours, such as nutrition (World Health Organization, 2002a). Dietary intakes are considered to play a significant role in the development of chronic diseases (Bolton-Smith *et al*, 1991; Smith & Brunner, 1997). Differences in dietary intake may be partly responsible for socioeconomic inequalities in the occurrence of these diseases (James *et al*, 1997; Smith & Brunner, 1997). Previous studies have shown that the consumption of some food items is socially patterned among adolescents (Hoglund *et al*, 1998; Roos *et al*, 2001; Sweeting *et al*, 1994). In general, less educated groups appear to consume a less healthy diet.

In 2000, the Belgian Science Policy launched a call for proposals on the topic of social cohesion in the society. The aim of the call was to contribute to the consolidation of knowledge potential in support of the federal socioeconomic policy. The call was an invitation to use existing databases for answering some of the remaining questions. It is in the context of this programme that the current study is fulfilled.

The objective of this study is to analyse the relation between adolescents' personal and parental educational training, and the adolescents' dietary habits. This is one of the remaining questions mentioned in the call.

Material and Methods

For the purpose of analysing the relation between adolescents' personal and parental education and the adolescents' dietary habits a dietary survey from 1997 (March – May), in which a random sample of adolescent residents of Ghent participated, was used. The study sample consisted of 656 adolescents (13 - 18 years) randomly selected on the basis of a multistage cluster sampling

technique. The design and methodology have been described in more detail elsewhere (Matthys *et al*, 2003). In brief, local private and public secondary schools (n=5) were randomly selected. They all agreed to participate. In Belgium, two major trajectories can roughly be distinguished in the educational system. One route consists of mainly theoretical courses, further called ‘general’ education. A second type of education focuses more intensively on the adoption of practical skills, further called ‘vocational’ education. Within each school, classes were selected in such a way that a uniform distribution over the age range 13 - 18 years was obtained. All students from the selected classes were asked to participate in the study. Of 656 adolescents (39.6% boys and 60.4% girls) 565 were considered eligible. Non-eligible students (n=91) were on sickness leave or had moved to other schools. Of the 565 eligible students, 411 (72.7%) actually participated. Because of missing data in the food diaries (see below) 70 students - of the 411 who actually participated - were excluded. Hence, results are reported for 341 of the 565 eligible students (60.3%). In this paper, results are given separately for boys (n=129) and girls (n=212).
Information letters were sent to directors, parents and the adolescents, who were all asked to give their written consent. The recruitment and the fieldwork were carried out in collaboration with the local Medical School Services.

A 7-day (consecutive) estimated food record method (semi-structured diary) was used to quantify food and nutrient intake. Information on the type (including brand names) and amount of food consumed was collected through an open entry format. The amount of food consumed was estimated using household measures (e.g., coffee spoon, cup,…) and standard portions (e.g., pieces, slices,…). Instructions for the completion of the diary (special attention was thereby given to the issue of estimation of portion sizes of food items an this was demonstrated with a number of standardised examples) and regular checks (every 2 days) for quality and completeness of the diaries were carried out by experienced dieticians. After completion, the diaries were processed into food quantities and codes by experienced dieticians on the basis of a standard protocol, including a Belgian standard manual on food portions and household measures. The storage of data on intake of individual food items was very detailed and contained altogether 745 different food items. Calculations of nutrient intake were done on the basis of the Dutch Food Composition Table (NEVO, 1993) and the Belgian Food Composition Tables (NUBEL, 1992; NUBEL, 1995) by means of a nutritional software package (BECEL-software packet) developed by the Unilever company. Average energy intake, nutrient intakes and intake of food items were calculated as the mean of the 7-day intake period.

A Variety Score (VS) was developed and is defined as the number of different food items that were consumed over the 7-day period and so reflect the respondents' food spectrum (Drewnowski *et al*, 1997). Both a "total Variety Score" and a "food group specific Variety Score" were used. For this purpose, the food items were classified into groups according to the Dutch Food Composition Table (NEVO, 1993).

Height and weight of the respondents were measured according to the standardised method proposed by the WHO (World Health Organization, 1995). Data on measured heights and weights were completed during the same period (1 week) as the food diary. The body mass index (BMI) was computed as weight (kg) divided by the square of height (m^2). Internationally accepted age and sex specific cut off points for body mass index related to overweight and obesity in children and adolescents developed by Cole and co-workers (Cole *et al*, 2000) were used.

In the general questionnaire, adolescents were asked about their place of residence (rural versus urban), the number of brothers and/or sisters, the educational level of both parents, the country of birth of both parents (born in Belgium or abroad) and the family status (parents living together or apart).

Socio-economic status is based on two indicators. The first indicator was based on the current educational level of the respondents. This variable distinguishes two levels, a 'general' education (mainly theoretical courses) and a 'vocational' training (focused on practical skills).

The second indicator of socio-economic status was based on the highest level of education that has been completed successfully by each parent of the respondents and is considered as a proxy measure of parental education. Parental education was categorised into high, medium and low. The first category was labelled high and represents the respondents whose both parents have a college education or university degree. The second category (medium) represents the respondents with only one parent having a college education or university degree. The last category (low) represents all respondents with no higher educated parent.

Both indicators were analysed by gender. A sub-analysis in girls was done on the basis of a combination of both indicators. The nutrient and food habits of girls following a general education with a high parental education were compared with girls following a vocational education with a low parental education.

Statistical analyses were performed using the SPSS software, version 12.0 (SPSS, Inc., Chicago, IL, USA). Descriptive statistics used means and standard deviations for continuous data. Kolmogorov – Smirnov test was performed to test for normality. Student's t-tests were used to compare the means of the different groups. Mann-Whitney and Kruskal-Wallis tests were used when variables were not normally distributed. Chi-square test was used to compare proportions. The associations between respondents' educational training, parental education and nutrient intake were investigated using generalised linear models. The following covariates were entered together: age, family status, place of residence, the number of brothers and/or sisters and the country of birth of both parents. Given the multitude of statistical tests, a P-value of < 0.01 was chosen in order to reduce the probability of false-positive findings.

The study was approved by the Ethical Committee of the Faculty of Medicine and Health Sciences of the Ghent University Hospital.

Results

The characteristics of the survey population by respondents' educational level and parental education are shown in Table 5.1. In boys, respondents with a vocational background are less represented. In both boys and girls, the drop-out of subjects (due to non-participation or incomplete diary) was significantly higher in students from vocational education as compared to students from general education (data not shown).

High parental education is proportionally most represented in boys while low parental education has the highest proportion in girls.

Table 5.1 also shows the proportion of overweight adolescents. In boys there are no differences between both educational levels. A higher proportion of overweight girls is found in the vocational educational level class in comparison with female adolescents with a classical educational level. In a similar way, in the low parental educational level class more overweight girls are found in comparison to girls with a high parental educational level.

Table 5.1: Distribution of respondents' educational training and parental educational level of the study sample according to gender and percentage of overweight adolescents (boys n = 129, girls n = 212)

	Boys			Girls		
	n	Age (mean)	% excess weight[b] (%obese)	n	Age (mean)	% excess weight[b] (%obese)
Educational training respondent						
General	112	15.1	6.3 (0.0)	101	15.4	7.1[a] (0.0)
Vocational	17	16.2	11.8 (0.0)	111	16.0	22.1[a] (8.3)
Educational level parents[c]						
High	47	15.1	2.1 (0.0)	59	15.6	3.4 (1.7)
Medium	30	14.9	10.0 (0.0)	32	15.9	12.5 (3.1)
Low	30	15.2	10.0 (0.0)	72	15.9	26.4 (8.3)

a: Missing data from two persons
b: Percentage of respondents with a BMI higher than 25, corresponding to the sex and age specific cut off points (Cole *et al*, 2000)
c: Missing data due to no information about the educational level of mothers or fathers or both

In Table 5.2, the mean energy and macronutrient intake (expressed as a percentage of the total energy intake) are shown according to gender and educational level. In general, boys have a higher energy intake than girls. The differences between boys and girls in terms of macronutrient intake, expressed as a proportion of energy, are small. The overall picture of energy contribution from macronutrients is very similar in boys and girls from both educational levels. Protein contributed on average 14.5 % to the energy intake, fat 36 % and total carbohydrates 49 %. Girls with a general education have a significant higher energy intake than girls following a vocational training. No other significant differences were found between 'general' and 'vocational' adolescents. Girls with a high parental education have a significant higher energy intake. In male adolescents there were no significant differences between different parental education groups.

Table 5.2: Mean (SD) energy intake (kcal), mean (SD) intake of macronutrients (in energy %) by gender, respondents' and parental education

	Educational level respondent			Parental education			
	General	Vocational	P – value	Low	Medium	High	P – value[a]
	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)	Mean (SD)	
Boys (n)	*112*	*17*		*30*	*30*	*47*	
Energy (kcal)	2634 (485.6)	2780 (689.9)	0.611	2571 (533.0)	2586 (510.5)	2650 (426.7)	0.615
Protein (E%)	14.5 (1.9)	13.3 (2.2)	0.025	14.4 (2.1)	15.0 (2.2)	14.3 (1.8)	0.259
Total Carbohydrates (E%)	48.8 (4.9)	48.1 (5.2)	0.407	49.8 (5.2)	47.8 (5.4)	49.2 (4.4)	0.235
Mono and disaccharides (E%)	23.7 (5.6)	24.6 (5.9)	0.775	25.6 (4.5)	22.8 (6.6)	23.6 (4.9)	0.064
Polysaccharides (E%)	25.1 (4.3)	23.4 (3.3)	0.093	24.2 (3.8)	24.9 (4.6)	25.5 (4.4)	0.492
Total Fat (E%)	36.1 (4.5)	36.9 (4.6)	0.274	35.5 (5.1)	36.4 (4.7)	36.0 (4.0)	0.785
SFA (E%)	15.5 (2.5)	15.6 (2.6)	0.765	15.1 (2.7)	15.6 (2.3)	15.7 (2.5)	0.849
MUFA (E%)	14.6 (2.2)	14.9 (1.9)	0.323	14.2 (2.3)	14.5 (2.2)	14.6 (2.2)	0.762
PUFA (E%)	6.1 (1.6)	6.5 (1.1)	0.100	6.2 (1.4)	6.2 (1.7)	5.8 (1.5)	0.281
Alcohol (E%)	0.6 (1.5)	1.6 (3.2)	0.851	0.3 (0.9)	0.9 (2.1)	0.6 (1.2)	0.342
Girls (n)	*101*	*111*		*72*	*32*	*59*	
Energy (kcal)	2080 (369.4)	1870.2 (494.9)	0.001	1862 (462.2)	1927 (387.6)	2190 (359.3)	<0.001
Protein (E%)	15.1 (2.5)	14.7 (2.7)	0.228	14.9 (2.6)	14. 6 (2.7)	15.2 (2.9)	0.601
Total Carbohydrates (E%)	49.2 (4.9)	49.2 (5.9)	0.951	48.7 (6.1)	49.8 (6.2)	49.9 (4.8)	0.311
Mono and disaccharides (E%)	24.2 (4.8)	23.9 (6.9)	0.669	23.2 (5.9)	25.2 (7.6)	25.2 (5.7)	0.221
Polysaccharides (E%)	24.9 (4.5)	25.4 (4.7)	0.531	25.5 (5.2)	24.6 (4.7)	24.8 (4.3)	0.790
Total Fat (E%)	35.3 (4.6)	35.6 (5.3)	0.732	35.8 (5.6)	35.3 (5.6)	34.5 (4.2)	0.195
SFA (E%)	15.7 (2.4)	15.1 (2.4)	0.079	15.2 (2.6)	15.4 (2.4)	15.3 (2.2)	0.868
MUFA (E%)	13.9 (2.3)	14.4 (2.7)	0.128	14.6 (2.7)	14.1 (2.9)	13.4 (2.1)	0.011
PUFA (E%)	5.8 (1.3)	6.1 (1.6)	0.133	6.0 (1.5)	5.8 (1.7)	5.8 (1.3)	0.695
Alcohol (E%)	0.4 (1.0)	0.6 (1.3)	0.987	0.6 (1.5)	0.4 (0.6)	0.4 (0.7)	0.952

E% = energy percentage; SFA = Saturated Fatty Acids; MUFA = Monounsaturated Fatty Acids; PUFA = Polyunsaturated Fatty Acids
a: Difference between low, medium and high

Table 5.3 shows the mean intake of selected micronutrients per day by gender and educational level. In male adolescents, no significant differences were found. Girls from a general educational level have significantly higher intakes of calcium, phosphorus, iron, magnesium, vitamin B1 and B2. Girls with a high parental education have a significant higher relative intake of calcium, phosphorus, iron, magnesium, vitamin B1 and B2. When the relative intake of micronutrients (mg/1000 kcal) is considered, boys from a general education level have a significant higher intake of iron than their counterparts. Based on relative intake, girls from a general educational level have significantly higher relative intakes of calcium, phosphorus, magnesium, vitamin B1 and B2. Girls with a high parental education have a significant higher relative intake of calcium, phosphorus and vitamin B2 (data not shown).

Based on the generalised linear models, the associations between respondents' educational training, parental education and nutrient intake were investigated. Results from the univariate analyses were all confirmed (data not shown).

The daily intake of food groups, expressed in grams, for the total group of adolescents according to gender, respondents' and parental education is presented in Table 5.4. In male adolescents, boys with a general educational level have a significantly higher intake of water. No differences were observed when boys of different parental education groups were compared. In all different sub-groups, the intakes of fruit, vegetables and water were below the recommendation of respectively 250 g/day, 300 g/day and 1500 ml/day, while the intake of meat was above the recommended 100 g/day.

In girls, the differences were even more pronounced. Girls with a general educational level have a higher intake of fruit, vegetables, breakfast cereals, cheese and milk & milk products, while their intake is significantly lower for soft drinks. Girls with a high parental education have a higher intake of cake & biscuits and milk & milk products. The same analyses were executed based on users only. In boys, no significant differences were observed. In girls with a general educational level a significantly higher intake of fruit, vegetables, milk & milk products and a significantly lower intake of soft drinks was found. In the consumer only analyses in female adolescents according to parental education, girls with a high parental education have a significant higher intake of bread, cake & biscuits and milk & milk products.

In comparison with the recommendations a similar trend as for boys was found.

Table 5.3: Mean micronutrient intake (SD) (in mg) by gender, respondents' and parental educational level, Belgian recommendations are shown for comparison

	Belgian Recommend Daily Allowance	Educational level respondent			Parental education			
		General Mean (SD)	Vocational Mean (SD)	P – value	Low Mean (SD)	Medium Mean (SD)	High Mean (SD)	P – value[a]
Boys (n)		*112*	*17*		*30*	*30*	*47*	
Calcium	1000 (11-14 y) – 1200 (15-18 y)	912.50 (337.53)	919.30 (431.17)	0.947	831.36 (333.72)	943.62 (335.35)	956.06 (355.17)	0.231
Phosphorus	900 (11-14 y) – 1000 (15-18y)	1479.03 (349.60)	1431.08 (417.77)	0.513	1387.33 (333.11)	1465.69 (344.62)	1512.89 (340.76)	0.453
Total Iron	10 (11-14 y) – 13 (15-18 y)	13.61 (2.92)	12.32 (2.66)	0.092	12.98 (2.97)	13.03 (2.67)	13.92 (3.03)	0.392
Magnesium	250-300	272.44 (68.97)	263.42 (76.30)	0.671	256.10 (63.38)	265.85 (75.14)	286.73 (67.09)	0.135
Vitamin B1	1.0 (11-14 y) – 1.2 (15-18 y)	1.50 (0.60)	1.69 (1.48)	0.189	1.43 (0.50)	1.59 (0.93)	1.64 (0.92)	0.711
Vitamin B2	1.4 (11-14 y) – 1.6 (15-18 y)	1.69 (0.55)	1.51 (0.61)	0.118	1.68 (0.68)	1.66 (0.49)	1.71 (0.49)	0.630
Vitamin C	65 (11-14 y) – 70 (≥15 y)	81.46 (48.05)	90.61 (55.54)	0.592	84.38 (41.10)	77.13 (35.73)	87.53 (58.69)	0.804
Girls (n)		*101*	*111*		*72*	*32*	*59*	
Calcium	1000 (11-14 y) – 1200 (15-18 y)	947.23 (358.03)	675.62 (290.79)	< 0.001	692.42 (327.82)	824.40 (339.78)	1017.51 (358.78)	< 0.001
Phosphorus	900 (11-14 y) – 1000 (15-18y)	1300.80 (367.31)	1032.98 (330.18)	< 0.001	1048.55 (352.61)	1102.93 (276.92)	1417.76 (374.89)	< 0.001
Total Iron	22 (11-14 y) – 21 (15-18 y)	10.75 (2.66)	9.41 (2.76)	< 0.001	9.52 (2.50)	9.85 (3.09)	11.29 (2.61)	< 0.001
Magnesium	250-300	237.96 (64.47)	192.74 (60.46)	< 0.001	195.40 (63.72)	206.11 (53.02)	254.59 (56.99)	< 0.001
Vitamin B1	0.9 (11-14 y) – 0.9 (15-18 y)	1.35 (1.13)	1.01 (0.60)	< 0.001	1.02 (0.52)	1.13 (0.70)	1.41 (1.22)	< 0.001
Vitamin B2	1.2 (11-14 y) – 1.3 (15-18 y)	1.51 (0.57)	1.16 (0.55)	< 0.001	1.15 (0.58)	1.34 (0.53)	1.63 (0.55)	< 0.001
Vitamin C	65 (11-14 y) – 70 (≥15 y)	84.36 (44.71)	72.69 (47.40)	0.012	72.49 (40.67)	86.03 (49.29)	88.29 (51.79)	0.136

a: Difference between low, medium and high

Table 5.4: The median intake of food groups (in grams) of the total group of adolescents according to gender, respondents' and parental education (Between brackets percentage users per sub-group)

	Educational level respondent		P-value	Parental education			P-value[a]
	General	Vocational		Low	Medium	High	
Boys (n)	*112*	*17*		*30*	*30*	*47*	
Fruit	68.93 (92)	34.29 (94)	0.097	82.79 (93)	59.79 (93)	63.86 (89)	0.493
Vegetables	118.11 (100)	106.29 (100)	0.179	109.46 (100)	113.93 (100)	132.14 (100)	0.263
Potatoes	137.29 (100)	111.14 (100)	0.533	143.00 (100)	133.79 (100)	117.86 (100)	0.205
Bread	190.00 (100)	167.86 (100)	0.554	154.29 (100)	191.57 (100)	195.00 (100)	0.058
Fruit juices	83.57 (76)	28.57 (59)	0.635	103.57 (80)	108.57 (73)	81.43 (75)	0.990
Soft drinks	403.57 (92)	466.69 (94)	0.423	459.06 (93)	378.21 (97)	328.57 (87)	0.233
Water	392.11 (96)	47.43 (71)	0.003	220.36 (83)	445.57 (97)	360.14 (98)	0.215
Cake & biscuits	33.29 (93)	19.29 (71)	0.166	32.29 (87)	30.79 (97)	35.57 (94)	0.974
Poultry	21.43 (75)	28.57 (88)	0.242	23.21 (73)	22.86 (70)	21.43 (81)	0.967
Breakfast cereals	4.29 (57)	.00 (29)	0.061	4.29 (57)	.21 (50)	7.14 (62)	0.597
Cheese	18.14 (92)	19.00 (88)	0.681	13.39 (90)	27.75 (90)	19.00 (94)	0.351
Milk & milk products	234.64 (99)	226.71 (94)	0.232	267.54 (100)	230.29 (100)	234.29 (98)	0.882
Fish	14.29 (65)	2.14 (53)	0.050	14.29 (70)	7.07 (53)	19.29 (68)	0.584
Meat & meat products	139.43 (100)	148.93 (100)	0.931	146.96 (100)	158.32 (100)	120.71 (100)	0.036
Sugar, confectionery, sweet fillings and sweet sauces	36.75 (99)	39.43 (100)	0.582	31.82 (100)	27.11 (100)	47.86 (100)	0.028
Fats, oils and savoury sauces	45.57 (100)	57.57 (100)	0.048	48.36 (100)	46.93 (100)	42.36 (100)	0.798
Girls (n)	*101*	*111*		*72*	*32*	*59*	
Fruit	110.07 (97)	77.43 (93)	0.002	79.82 (93)	95.18 (100)	117.14 (97)	0.149
Vegetables	106.14 (100)	80.43 (100)	0.007	91.25 (100)	102.89 (100)	104.71 (100)	0.156
Potatoes	94.00 (100)	90.00 (98)	0.976	96.43 (100)	90.89 (100)	93.14 (100)	0.718
Bread	144.43 (100)	139.00 (99)	0.083	134.71 (99)	137.64 (100)	158.21 (100)	0.013
Fruit juices	121.43 (83)	82.14 (72)	0.031	94.00 (83)	108.57 (72)	121.43 (81)	0.763
Soft drinks	92.86 (77)	204.29 (93)	<0.001	166.43 (92)	161.79 (88)	142.86 (76)	0.128
Water	482.14 (98)	371.43 (97)	0.014	351.43 (99)	432.25 (100)	441.36 (95)	0.429
Cake & biscuits	27.14 (93)	22.71 (89)	0.014	21.07 (92)	25.00 (94)	36.86 (95)	0.003
Poultry	18.86 (72)	17.86 (64)	0.646	17.61 (61)	17.14 (63)	19.71 (81)	0.370
Breakfast cereals	4.29 (55)	.00 (30)	<0.001	.00 (33)	.89 (53)	4.29 (54)	0.017
Cheese	29.29 (97)	17.86 (90)	0.005	17.86 (93)	24.57 (97)	30.00 (95)	0.116
Milk & milk products	245.36 (99)	124.43 (93)	<0.001	117.50 (93)	151.54 (94)	352.86 (100)	<0.001
Fish	7.29 (63)	10.71 (66)	0.804	8.14 (65)	8.36 (69)	17.07 (66)	0.415
Meat & meat products	83.21 (97)	98.79 (100)	0.301	102.50 (100)	83.54 (100)	78.50 (97)	0.119
Sugar, confectionery, sweet fillings and sweet sauces	27.86 (100)	25.29 (99)	0.069	23.57 (100)	26.64 (100)	32.86 (100)	0.012
Fats, oils and savoury sauces	31.57 (100)	32.79 (100)	0.579	32.18 (100)	31.39 (100)	34.64 (100)	0.618

a: Difference between low, medium and high

The total Variety Score was higher in boys following a general educational training. On food group level the Variety Score was not significant different. Based on the parental education, there is no significant difference in boys. The total Variety Score was higher in girls following a general educational training. Girls with a general educational training have a significant higher Variety Score for fruit, vegetables, breakfast cereals, cheese, milk & milk products, cake & biscuits, sugar & confectionery and a significant lower Variety Score for soft drinks. Girls with a high parental education have a significant higher total Variety Score and food group specific Variety Score for cake & biscuits and milk & milk products (data not shown).

Table 5.5: Mean energy intake (kcal), mean contribution to energy of macronutrients (E%), relative micronutrient intake (mg/1000 kcal) and mean food group intake in female adolescents according to the respondents' education and parental education

	Educational level respondent and parental education		
	General educational level and high parental education	Vocational educational level and low parental education	P – value
	Mean (SD)	Mean (SD)	
N	*47*	*56*	
Energy (kcal)	2210 (370.2)	1807 (485.5)	<0.001
Protein (E%)	15.2 (2.4)	14.8 (2.5)	0.292
Total Carbohydrates (E%)	50.2 (4.3)	49.2 (6.2)	0.255
Mono- disaccharides (E%)	25.2 (4.9)	23.1 (6.1)	0.045
Polysaccharides (E%)	24.9 (4.3)	26.2 (4.9)	0.311
Total fat (E%)	34.5 (3.9)	35.4 (5.8)	0.181
SFA (E%)	15.4 (2.2)	14.9 (2.7)	0.560
MUFA (E%)	13.3 (1.9)	14.4 (2.9)	0.012
PUFA (E%)	5.8 (1.2)	6.0 (1.4)	0.408
Calcium (mg/1000 kcal)	481.83 (154.23)	349.86 (124.54)	<0.001
Phosphorus (mg/1000 kcal)	670.20 (183.59)	551.11 (114.91)	<0.001
Total Iron (mg/1000 kcal)	5.35 (1.29)	5.40 (1.41)	0.832
Magnesium (mg/1000 kcal)	120.43 (26.05)	106.96 (24.38)	0.005
Vitamin B1 (mg/1000 kcal)	0.71 (0.70)	0.52 (0.19)	0.010
Vitamin B2 (mg/1000 kcal)	0.79 (0.27)	0.59 (0.20)	<0.001
Vitamin C (mg/1000 kcal)	40.93 (24.95)	41.63 (24.99)	0.952
Fruit	133.02 (105.78)	97.87 (83.57)	0.083
Vegetables	121.53 (61.82)	100.10 (55.39)	0.062
Potatoes	104.56 (60.68)	106.36 (59.55)	0.830
Bread	168.19 (51.23)	135.33 (50.72)	0.004
Fruit juices	165.60 (166.46)	126.04 (145.76)	0.322
Soft drinks	164.53 (208.63)	251.14 (224.17)	0.019
Water	520.23 (362.17)	410.53 (337.09)	0.095
Cake & biscuits	42.38 (29.03)	24.20 (19.99)	<0.001
Poultry	24.99 (20.62)	24.89 (26.13)	0.553
Breakfast cereals	9.78 (14.45)	3.96 (7.84)	0.001
Cheese	29.09 (21.17)	21.07 (19.40)	0.026
Milk & milk products	403.91 (273.78)	154.60 (187.49)	<0.001
Fish	17.95 (19.45)	14.02 (15.40)	0.463
Meat & meat products	86.29 (46.49)	95.06 (50.05)	0.219
Sugar, confectionery, sweet fillings and sweet sauces	40.91 (28.53)	26.76 (17.45)	0.004
Fats, oils and savoury sauces	36.43 (17.45)	33.60 (17.45)	0.433

Table 5.5 shows energy, macro-, micronutrient and food group intake of female adolescents according to the combination of their own education and the parental education. Girls following a general educational training with a high parental education have a significant higher intake of energy, calcium, phosphorus, magnesium, vitamin B1 & B2, bread, cake & biscuits, breakfast cereals, milk & milk products and sugar & confectionery compared to girls following a vocational educational training with a low parental education. More detailed data show that girls from a general education with a high parental education consume significantly more low-fat milk products, skimmed milk products and low-fat fresh fish than their counterparts. Girls from a vocational education with a low parental education consume significantly more high-fat meat (data not shown in Table).

Discussion

This study provides data on estimated nutrient and food intake in a sample of Belgian adolescents, allowing an examination of social variations in the dietary habits. It is – to our knowledge – for the first time that a quantification of nutrient and food intake in different social groups in Belgian adolescents has been undertaken. However, an important disadvantage of the present study is its reliance on an existing database which was initially not established to analyse the dietary habits in relation to social differences. Particularly, the limited number of boys in vocational education causes a lack of power in the analyses. The originally selected sample size contained only 56 boys who follow a vocational education. This is explained by the study design where schools with vocational education were less well represented. It is not clear in what way this may have affected the results of the study but it does not infringe on the value of the within-girl analyses. On the other hand, the strength of the study is the use of a 7-day estimated food record.

In this study, the social stratification within the adolescent population is based on two indicators, namely the respondents' educational training and the parental education. The classification of the respondents' educational level was based on the school register. In the current study there could be a selection bias induced because of the higher drop-out rate of male subjects from the category 'vocational'. Therefore, the conclusions are focussed on the female adolescents. The parental education was reported by the adolescents. The validity of the adolescents' report of parental education can be questioned. A Norwegian study found that the strength of agreements between adolescents' and parents' reports of parental education was rather weak (Lien *et al*, 2001a). This could be a limitation of the study. Nevertheless, cross-study comparisons are difficult, owing to differences in the measurement of lifestyle behaviours, differences in classification of the different European education systems, differences in the dietary assessment methods or differences in the study samples.

Based on the anthropometrical data the overall nutritional status could be determined. The proportion of overweight and obese adolescents is higher in girls with a vocational educational level and in girls with a low parental education. No differences were found in boys. The higher prevalence of obesity in subjects with a lower social status is in line with other Belgian studies (De Spiegelaere *et al*, 1998; Stam-Moraga *et al*, 1999). Based on school health files of 2 607 children, social inequality – based on parents' professions and the status of their activity – in the prevalence of obesity in Belgian girls was found (De Spiegelaere *et al*, 1998). A similar conclusion was found in adults, based on the Belgian Interuniversity Research on Nutrition and Health. Stam-Moraga and co-workers found that compared to the lowest educated women, the proportion of obese was significantly lower in higher education groups. Results from neighbouring countries confirm that the prevalence of obesity is highest in lower social classes (Hulshof *et al*, 2003; Klein-Platat *et al*, 2003; Smith & Brunner, 1997).

Based on the findings about energy intake and macronutrient intake almost no differences were found between subjects according to their social status. In boys, with the exception of significant differences in protein intake according to the respondents' educational level, no differences were found. In girls, differences in monounsaturated fatty acids and energy intake were found. One could raise the question whether the observed difference in energy intake is real or whether it is the consequence of underreporting. The mechanism of under- and overreporting could play a role in our study but due to the lack of complementary data (e.g., physical activity degree) and the unavailability of a valid indicator to detect adolescent under- and over-reporters, it remains

difficult to deal with this issue. However, in the current study the lowest mean ratio of energy intake to estimated basal metabolic rate was observed in girls with a lower educational level (EI/BMR 1.28 for girls with a low educational level versus 1.44 – 1.52 for girls with a high educational level). The current results indicate that the influence of underreporting might be overrepresented in girls belonging to the low social class. In boys, no differences were found.
Some studies concluded that there is not much evidence of energy and macronutrient intake differences. Low social classes have been described as efficient purchasers of calories and nutrients per unit cost. Nevertheless, the intake of micronutrients is usually much lower in the less advantaged (Dowler *et al*, 1997; Nelson, 2000). The current study found that girls who follow a vocational education and/or with a low parental education were associated with a lower intake of most minerals and vitamins both in absolute amounts and expressed per 1 000 kcal. Total iron intake is an exception on the above finding. Similar results were found in British and Spanish adolescents, mainly in girls (Nelson, 2000; Tur *et al*, 2004). These observations are directly related to health outcomes, according to British data that pointed out that micronutrient and antioxidant intakes have the most likely nutritional influences on health inequalities (Smith & Brunner, 1997).

In the current study social class differences were more pronounced on the food level than on the nutrient level. The findings about the higher consumption of cheese in subjects with a higher educational level are in line with the conclusions of a systematic review of social differences in food habits in Europe (Sanchez-Villegas *et al*, 2003). There was not enough evidence to support that milk intake is different according to educational levels (Sanchez-Villegas *et al*, 2003). A survey from the Netherlands confirmed the current results about cheese and milk & milk products intake (Hulshof *et al*, 1991). In our study, the consumption of soft drinks is higher in subjects with a low educational level or a low parental education. These findings are supported by other surveys (Sweeting *et al*, 1994; Vereecken *et al*, 2004). The average consumption of fruit and vegetables was higher in our subjects belonging to the higher educational groups. Previous studies have shown that the intakes of fruit and vegetables are significantly associated with the educational level (Hulshof *et al*, 2003; Tur *et al*, 2004; Vereecken *et al*, 2004). A systematic review of socioeconomic differences in food habits in Europe showed that, particularly in Northern and Western European countries, a higher social status is associated with a higher consumption of fruit and vegetables (Irala-Estevez *et al*, 2000). The current results are in agreement with these previous studies, mainly in girls. Subjects with a higher educational level tend to be more aware of the characteristics of a healthy diet (Margetts *et al*, 1997) and have more knowledge about food items which are healthier (Hjartaker & Lund, 1998; Margetts *et al*, 1997; Martinez-Gonzalez *et al*, 1998). To the extent that better awareness and knowledge are translated into healthier dietary habits, this might partly explain the differences in food consumption between social classes. On the other hand, poverty and lower income also may restrict access to healthy food (Dowler & Dobson, 1997; James *et al*, 1997). Nevertheless, the intake of fruit and vegetables of the total population, irrespective of social class, is below the national recommendations (Vlaams Instituut voor Gezondheidspromotie, 2003).

Studies have shown that dietary variety is associated with increased consumption of fruit and vegetables (Drewnowski *et al*, 1997) and decreased cardiovascular risk factors (Hsu-Hage & Wahlqvist, 1996); dietary variety has been found to be inversely associated with age-adjusted risk of mortality (Kant *et al*, 1995). Based on the results of the Variety Score, girls from the general educational level consume a larger variety of more healthy food groups (fruit, vegetables), although they consume also a greater variety of cake & biscuits, sugar & confectionery but less of soft drinks. Similar results were found when parental education was used as indicator. Based on the current findings girls with a higher educational level consume a more varied diet that can favourably affect health.

In this study, as in others (Dynesen *et al*, 2003; Friel *et al*, 2003; Hjartaker & Lund, 1998), respondents' educational training seems to be a relevant indicator of social status explaining differences in dietary habits. Adolescents following a general educational training or with a high parental education consume more healthy foods, have a higher intake of micronutrients and a higher Variety Score. Based on these findings, baseline data is now provided for health promotion campaigns. More specific, it is known that nutritional education is important in all different educational options in secondary schools (American Dietetic Association, 2003; Perez-Rodrigo & Aranceta, 2001). But at the same time the results of the current study show that segmenting and targeting is important in health promotion. Different educational options need another approach and message content to deal with health promotion.

In general, one could establish that the total population does not reach the national recommendations (Nationale Raad voor de Voeding, 1996; Vlaams Instituut voor Gezondheidspromotie, 2003), but the situation is worst in lower social classes. Although the sample is small, these findings demonstrate trends which highlight the need for continued health promotion efforts to improve the diet of adolescents in all social classes in Belgium but particularly in lower social groups. Therefore public authorities trying to minimise social inequalities in health need regularly updated information about the social differentiation of health-related lifestyles. Social differences in dietary habits change over time (Prattala *et al*, 1992) and it is important to be aware not only of the current differences but also of any subsequent change in the future.

6

RISK ASSESSMENT OF DIETARY ACRYLAMIDE INTAKE IN FLEMISH ADOLESCENTS

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Abstract

Acrylamide has recently been found in a range of heat treated food items. As it is a neurotoxic agent and a probable, human carcinogen (IARC 2A), human exposure to this chemical might constitute an important public health issue. The purpose of the study was to estimate the acrylamide intake in Flemish adolescents (based on 7-day food record) and to evaluate the possible health risks due to the exposure. The Belgian Federal Agency for the Safety of the Food Chain collected 150 food items from different supermarkets and restaurants to analyse the acrylamide level. The limit of quantitation was 30 µg acrylamide/kg foodstuffs. Exposure modelling was based on Monte Carlo simulations. The estimated dietary intake of acrylamide per person given as the 5^{th}, 50^{th} and 95^{th} percentile were 0.19, 0.51 and 1.09 µg/kg bw/d. Bread, despite its low acrylamide content, is relevant as a source of acrylamide exposure at the lower percentiles. At higher percentiles the contribution of French fries and crisps is more important. It must be emphasised that the exposure assessment has several limitations. Risk of neurotoxicity seems negligible. The relevance of current intake levels in terms of cancer risk remains a subject of debate.

Introduction

In April 2002, scientists in Sweden – quite unexpectedly – discovered large amounts of the chemical acrylamide ($CH_2 = CHCONH_2$) in foods rich in starch that have been heated at high temperatures (Swedish National Food Administration, 2002b). These included crisps, French fries, bread and crisp breads. Acrylamide may be formed through the Maillard reaction from amino acids and reducing sugars (Mottram *et al*, 2002; Stadler *et al*, 2002). Acrylamide has been shown to be neurotoxic in humans and laboratory animals (Food and Agricultural Organization / World Health Organization, 2002; International Agency for Research on Cancer, 1994). It has been classified as a Group 2A carcinogen by the International Agency for Research on Cancer (International Agency for Research on Cancer, 1994). This might represent a potential threat to public health (European Commission, 2002a; Food and Agricultural Organization / World Health Organization, 2002). In view of this, the FAO/WHO Expert Consultation urges more research on acrylamide in food. It includes formal research, surveillance/monitoring and industry investigations (Food and Agricultural Organization / World Health Organization, 2002). Against that background a post-hoc analysis was made using an existing food consumption database.

The purpose of the current study was to estimate the acrylamide intake in a Belgian subpopulation, namely Flemish adolescents and to evaluate the possible health risks due to this exposure. In the present communication, a risk assessment of acrylamide intake is described and discussed.

Material and methods

Sampling and chemical analysis

In 2003, the Belgian Federal Agency for the Safety of the Food Chain collected 150 food items from different supermarkets and restaurants. The samples comprised baby's biscuits, bread, small bread type, crisps, chocolate, choco-spread, French fries, coffee, breakfast cereals, gingerbread, sweet spiced biscuit, biscuits and popcorn. The choice of food items was based on what was known end of 2002–early 2003 on the occurrence of acrylamide in foodstuffs (FOD VVVL, 2002; Food and Agricultural Organization / World Health Organization, 2002; Norwegian Food Agency, 2002; Swedish National Food Administration, 2002a; van Donkersgoed *et al*, 2002), priority was given to food groups that, in those studies, had been shown to contain relevant amounts of acrylamide.

The acrylamide analysis was carried out by a Beltest accredited laboratory of the Department of Pharmaco-Bromatology of the Scientific Institute of Public Health in Brussels, by using a validated method according to the ISO 17025 standards. In the experimental procedure acrylamide is extracted from food with water before a clean-up of the extract on Solid Phase Extraction combining Oasis HLB and BondElut Accucat cartridges as described in the US FDA methodology (www.cfsan.fda.gov). A further concentration step by evaporation was introduced before analysis using the LC–MS–MS technique. The limits of the method are respectively 15 and 30 µg acrylamide/kg foodstuff for detection and quantitation. The acrylamide content of coffee was partially determined on the basis of coffee powder and was recalculated to coffee drink using a conversion factor of 0.046 proposed by Dooren *et al* (Dooren *et al*, 1995). Also liquid coffee was analysed. For the intake estimation, levels of acrylamide below the limit of quantitation were set at one third of that limit (4 samples < limit of quantitation). No data were available on the acrylamide content of rusk, therefore the authors used Dutch contamination data with a reporting limit of 60 µg/kg (Konings *et al*, 2003). Other food groups, which were not analysed because they are not known to contain acrylamide, were supposed to contain no acrylamide at all.

Due to the restricted number of analyses a major assumption was made: acrylamide contents of analysed food items were also applied to a number of related food items for which no analytical data were available. Food items were considered related when a similar type of food technology was used to produce them, e.g., salty crisps and sweet and sour crisps. The type and amount of amino acid and reducing sugar of the related products were not considered. Although the acrylamide levels vary among product categories and within categories (Petersen, 2002; Svensson *et al*, 2003), we assumed that differences between food items of a certain food group would be small.

Exposure estimation

We started from a food intake survey carried out in Spring 1997, the most recent, detailed dietary survey available for Belgium (Matthys *et al*, 2003). That survey was based on a representative sample of 341 adolescents (129 boys and 212 girls), aged 13–18 years, from the region of Ghent (±250,000 inhabitants) in the Dutchspeaking part of Belgium. Different educational options – classical education (mainly theoretical courses) and vocational training (based on practical skills) – were proportionally represented in the sample. A 7-day estimated food record method (semi-structured diary) was used to quantify food and nutrient intake. Instructions for the completion of the diary and regular checks for quality and completeness of the diaries were carried out by experienced dieticians. The storage of data on intake of individual food items was very detailed and contained altogether 745 different food items. Although the adolescent survey was conducted in 1997, it was assumed that the current intake of relevant acrylamide containing foods has not substantially changed since 1997.

Weight of the respondents was measured according to the standardised method proposed by the WHO (World Health Organization, 1995). Data on measured weights were completed in the same period (within one week) as the food diary.

Dietary exposure distributions for acrylamide were generated in a probabilistic way for the total adolescent population and for boys and girls separately, using a so called one-dimensional Monte Carlo simulation programme (see Figure 6.1) (Cullen & Frey, 1999; Petersen, 2000).

In this approach, a distribution of food consumption from the target population and available distributions of acrylamide levels in the foods under consideration are being sampled repeatedly in a random way. During each sampling round across these databases, intake data from the subjects are being linked to contamination data, thereby generating series of theoretically occurring acrylamide intakes on individual level.

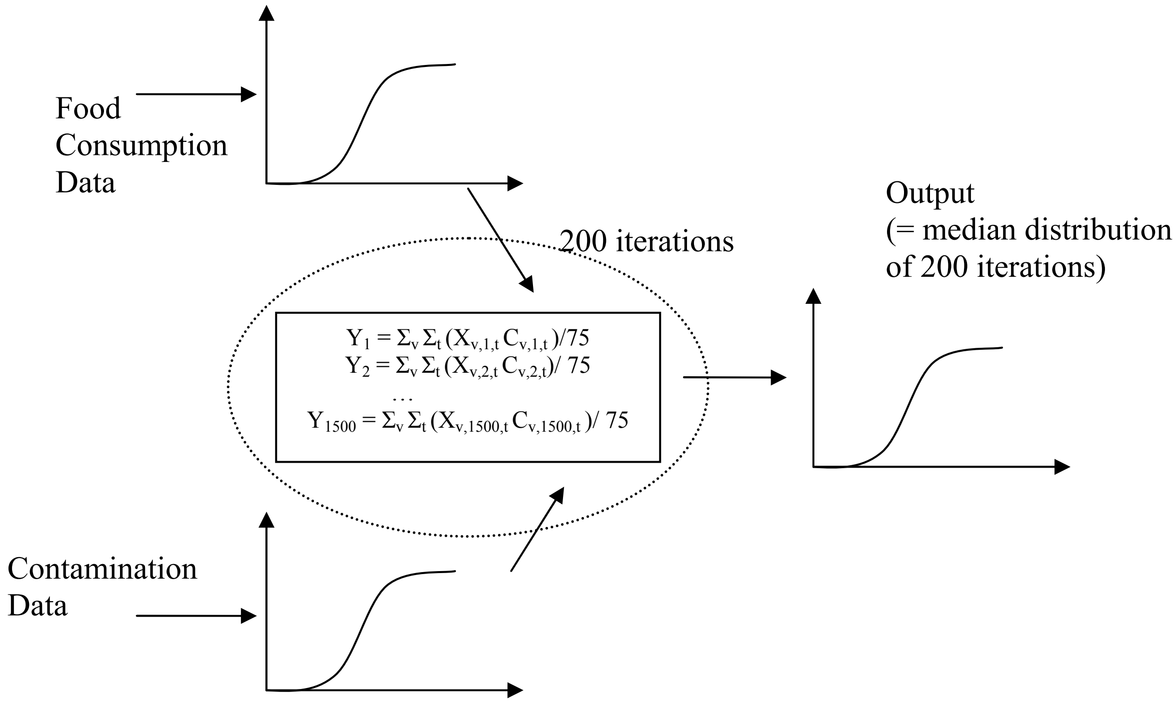

Figure 6.1: Graphical presentation of the one-dimensional Monte Carlo simulation model used in the current study.

Mathematically, a subject's usual daily acrylamide intake is computed according to the equation:

$$Y_i = \sum_v \sum_t \left(X_{v,i,t} C_{v,i,t} \right) / T$$

where $X_{v,i,t}$ is the amount (g) of relevant acrylamide containing food item v (see above), consumed by subject i, at day t (t = 1, …, T) and $C_{v,i,t}$ is the concentration of acrylamide in a food item, expressed by µg/kg food stuff, randomly chosen.

For each subject i, the average body weight adjusted daily intake via food of acrylamide (DIi) is computed according to the equation: DIi=Yi/bw$i$, where Yi is the subject's average total daily intake of acrylamide and bw$i$ is body weight (kg).

Sampling rounds across databases are being repeated in the same way until saturation is reached, i.e., until further sampling does not add measurably to the available information.

For the purpose of optimising integration of respectively the intra-individual and inter-individual variability in food consumption in the overall exposure assessment model, the 7-day diary was extended to a fictive 75 day diary for all subjects (by simply copying the diary repeatedly until 75 days are reached) and the number of subjects was artificially extended to 1500 (by randomly copying subjects until the target number was reached). The former procedure thereby increases the likelihood of combining all existing food combinations and portions in the diaries with all available contamination values for these foods. The latter procedure accounts predominantly for the uncertainty arising from a relatively small sample size.

Finally, the above described procedure has been repeated in 200 consecutive loops, yielding 200 theoretical distributions of acrylamide intake. The median distribution from these 200 obtained distributions is the one finally reported in this paper. All simulations presented were run using the Hexalog software (Aardex Ltd.).

Reference doses and cancer slope factors

A Joint FAO/WHO Consultation recognized neurotoxicity as the key non-cancer, non-genotoxic effect of acrylamide in humans (Food and Agricultural Organization / World Health Organization, 2002). A No Observed Adverse Effect Level (NOAEL) for acrylamide-induced neuropathy was identified as 0.5mg/kg body weight/day in a chronic rat experiment (Spencer & Schaumburg, 1974). Based on that life long experiment, an oral reference dose (RfD) of 5 µg/kg bw/d can be calculated – by dividing the NOAEL by an assessment factor (AF) of 10×10 for inter-species and intra-species extrapolation – following the conventional EU procedure to determine an acceptable daily intake for pesticides in food and in analogy with the US-EPA procedure given below. It can be assumed that an intake below this reference dose of 5 µg/kg bw/d will be without appreciable risk for neurotoxic health effects in man.

The US-EPA (1993), however, based its risk assessment on neurotoxic effects observed in subchronically exposed rats (Burek *et al*, 1980), where a No Observed Effect Level (NOEL) of 0.2mg/kg bw/d was identified. Applying an AF of $10 \cdot 10 \cdot 10$ (for inter-species, intra-species, and subchronic to chronic extrapolation), they calculated an oral RfD of 0.2 µg/kg bw/d for this non-carcinogenic effect (US Environmental Protection Agency, 1993). This approach, therefore, identifies a significantly lower intake below which it is assumed that no appreciable neurotoxic effects will occur in man.

Acrylamide has been shown to be clastogenic and carcinogenic in the animal (Friedman, 2003). It is classified as a probable human carcinogen (International Agency for Research on Cancer, 1994; US Environmental Protection Agency, 1993) or as a substance, which should be regarded as if carcinogenic to man (http://ecb.jrc.it/classificationlabelling/) (European Commission, 2002b). Within the EU regulatory framework, no quantitative risk estimation is performed for that kind of substances and intake should remain as low as possible. Starting from life long animal experimental data, however, the dose that would produce cancer in 25% of the animals exposed can be calculated and a linear extrapolation towards zero can be performed. This leads to an oral cancer slope factor (CSF) applicable to man of 1.6 (mg/kg bw/d)$^{-1}$ (Dybing & Sanner, 2003). This predicts that the number of extra cancers caused over a lifetime is equal to the daily acrylamide dose multiplied by 1.6 (mg/kg bw/d)$^{-1}$, e.g., a daily intake of 1 µg/kg body weight/day could produce 1.6 extra-cancers per 1000 men exposed. Applying a linearised multistage (LMS) model to the animal experimental data, the US-EPA (1993) derived an oral cancer slope factor (CSF) for man of 4.5 (mg/kg bw/d)$^{-1}$ (US Environmental Protection Agency, 1993). Similar estimations regarding intake via water, led to drinking water unit risks of 1.3 (µg/l)$^{-1}$ (US Environmental Protection Agency, 1993) or 5 (µg/l)$^{-1}$ (World Health Organization, 1996).

Results

Intake estimation

In Table 6.1 the acrylamide levels (µg/kg) in various food groups are shown. The levels of acrylamide varied considerably between single food items within food groups. In Table 6.1 the food consumption of the food groups used in the intake calculations are shown.

Figure 6.2 shows the cumulative distribution function of the total acrylamide. The exposure to acrylamide via food in the total Flemish adolescent group ranges from 0.19 µg/kg bw/d at the 5th percentile, over 0.51 µg/kg bw/d at the 50th percentile, to 1.09 µg/kg bw/d at the 95th percentile.

For boys the range varies from 0.23 (P5) over 0.64 (P50) to 1.26 (P95) µg/kg bw/d, and for girls from 0.17 (P5) over 0.46 (P50) to 0.94 (P95) µg/kg bw/d. Figure 2 also shows the distribution of the intake via different food groups. The percentile distribution for each food group is estimated independently. Therefore, the total intake at a certain percentile is different from the sum of the different food items at that percentile.

Table 6.1: Acrylamide amounts (µg/kg) of food groups and consumption (g/day) of those food groups in adolescents.

	Contamination data (µg/kg food stuff)		Consumption data (g/day)		
			All (n=341)	Boys (n=129)	Girls (n=212)
	Number of samples	Median (Min-Max)	Mean (P50-P95)	Mean (P50-P95)	Mean (P50-P95)
Baby's biscuits	5	324 (225- 1217)	1.97 (0-15)	1.20 (0-0)	2.44 (0-25)
Bread	6	30 (27-36)	119.30 (100-315)	146.45 (135-360)	102.77 (90-265.63)
Small bread type	4	38 (29-51)	44.31 (0-200)	47.65 (0-207.60)	42.28 (0-192.50)
Crisps	29	676 (38-1612)	5.93 (0-45)	7.91 (0-60)	4.72 (0-30)
Chocolate	3	108 (104-109)	9.73 (0-50)	12.34 (0-60)	8.14 (0-50)
Choco-spread	2	88.5 (65-112)	7.64 (0-40)	10.30 (0-60)	6.02 (0-30)
French fries	33	254 (56-729)	39.88 (0-250)	45.84 (0-300)	36.26 (0-200)
Biscuits	6	143 (20-1514)	17.51 (0-83)	19.11 (0-90)	16.53 (0-79.75)
Coffee	11	114 (11-1291)	44.90 (0-300)	46.25 (0-300)	44.07 (0-293.75)
Gingerbread	5	1403 (108-1697)	0.88 (0-0)	1.75 (0-0)	0.35 (0-0)
Breakfast cereals	20	135 (37-623)	9.17 (0-60)	13.79 (0-75)	6.36 (0-40)
Popcorn	5	160 (129-216)	0.14 (0-0)	0.06 (0-0)	0.19 (0-0)
Sweet spiced biscuit	5	204 (160-677)	1.49 (0-14)	2.17 (0-21)	1.08 (0-0)

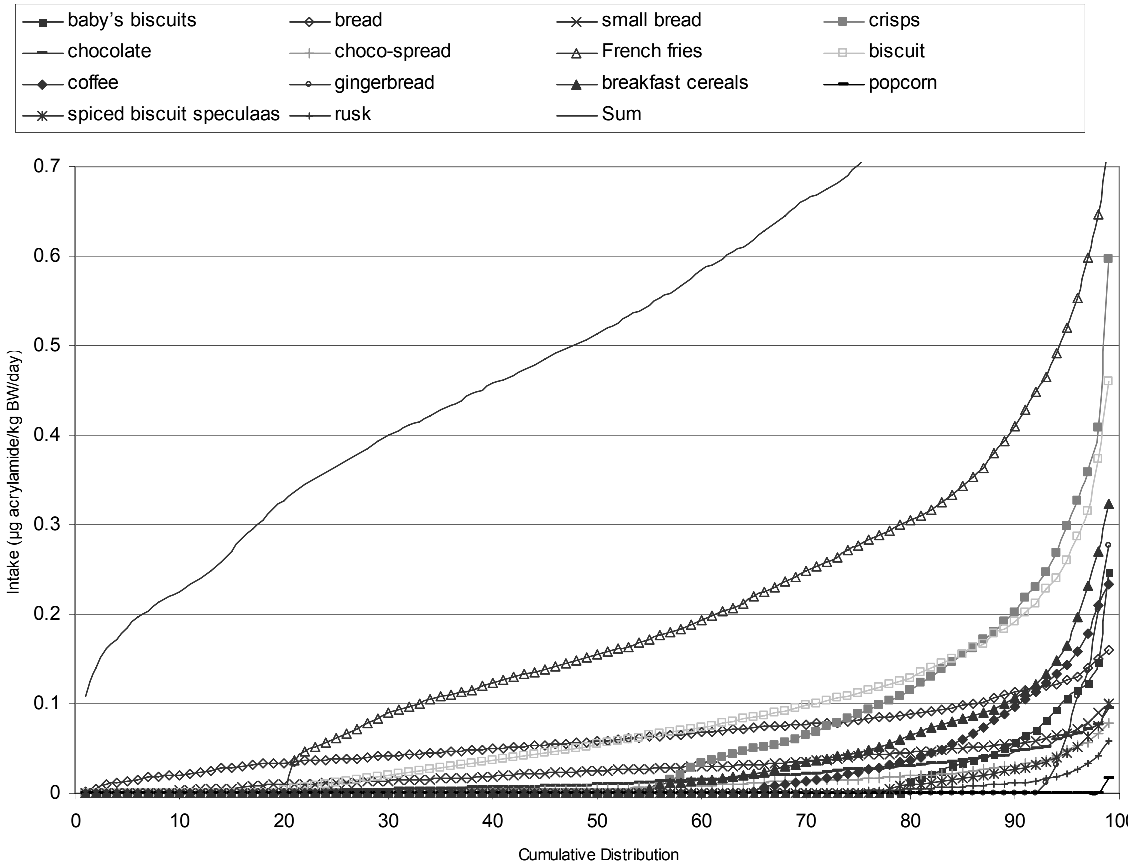

Figure 6.2: Cumulative distribution functions in the background intake of acrylamide (µg/kg bw/day). The cumulative distribution functions for total intake and for the intakes via different food items are estimated separately. Therefore, the total intake at each percentile is not equal to the sum of the intake via the individual food items.

The separate analysis for each food group or food item separately, indicates that bread is the most important contributor of background acrylamide-intake for the lower percentiles (up to the 21st percentile). From the 21st percentile French fries are the main source of acrylamide exposure. From the 55th percentile on, biscuits are the second important source of acrylamide intake. For the subgroups with higher intakes, above the 93rd percentile, French fries, crisps, biscuits, breakfast cereals and coffee (in order of importance) become the more important sources of acrylamide. Other food items, such as popcorn, chocolate, choco-spread, gingerbread and sweet spiced biscuit, contribute little to the total exposure via food (Table 6.2).

Table 6.2 Variation in simulated daily acrylamide exposure in the adolescent population, via French fries, crisps, bread, biscuit and in total.

Percentile	via French fries (µg AA/kg bw/day)°	via crisps (µg AA/kg bw/day)°	via bread (µg AA/kg bw/day)°	via biscuit (µg AA/kg bw/day)°	total exposure (µg AA/kg bw/day)°
1	0	0	0.002	0	0.108
5	0	0	0.013	0	0.185
20	0	0	0.034	0.004	0.327
50	0.155	0	0.057	0.055	0.513
55	0.171	0	0.063	0.064	0.545
75	0.276	0.087	0.081	0.111	0.702
95	0.521	0.298	0.127	0.260	1.089
99	0.725	0.596	0.159	0.459	1.411

° AA: acrylamide and bw: body weight

Intake and health based exposure limits

The intakes shown in Figure 6.2, including the highest 99th percentile of intake, i.e., for boys, 1.41 µg/kg bw/d, are lower than the dose of 5 µg/kg bw/d below which neurotoxic effects in man would be negligible (see Section Material and Methods). They are, however, all above the US-EPA RfD for neurotoxicity of 0.2 µg/kg bw/d. On the basis of the CSF of 1.6 (mg/kg bw/d)$^{-1}$ (Dybing and Sanner, 2003), a lifetime cancer cumulative incidence in our population would vary from 2.9×10^{-4} for an acrylamide intake at 0.18 µg/kg bw/d (3rd percentile), over 8.2×10^{-4} at 0.51 µg/kg bw/d (50th percentile), up to 17.4×10^{-4} at 1.09 µg/kg bw/d (95th percentile).

Discussion

The median dietary acrylamide intake in Flemish adolescents can be estimated to be 0.51 µg/kg bw/d. The 95th percentile of intake is 1.09 µg/kg bw/d. Both median and 95th percentile are higher in boys than in girls. This is explained by the fact that boys have a higher intake of food than girls. Our study addresses the adolescent population since in Belgium, up to date, detailed consumption data for people older than 18 years of age are lacking. At a Joint FAO/WHO Consultation it was stated that the average intakes for the general population were estimated to be in the range of 0.3 - 0.8 µg acrylamide/kg bw/d. In Sweden, a median dietary intake of acrylamide of approximately 0.38 µg/kg bw/d and a 95th percentile intake of 0.89 µg/kg bw/d (assuming a body weight of 70kg) was calculated for 1211 individuals between 18 and 74 years old (Svensson *et al*, 2003). In Norway the median acrylamide exposure varied from 0.41 to 0.42 µg/kg bw/d, respectively males and females between 16 and 79 years old. In Norwegian 13 years old youngsters the median exposure varied from 0.30 to 0.28 µg/kg bw/d, respectively for boys and girls (Dybing & Sanner, 2003). In the Netherlands the median exposure of acrylamide for 7–18 years children was estimated to be 0.2 µg/kg bw/d and the 95th percentile was 0.9 µg/kg bw/d (Konings *et al*, 2003). Based on a duplicate diet study, the mean acrylamide exposure in a Swiss population (16–67 years) was 0.28 µg/kg bw/d (Swiss Federal Office of Public Health, 2002). Based on the USDA Continuing Survey of Food Intake for Individuals an average acrylamide exposure of 0.8 µg/kg bw/d was estimated (Petersen, 2002). It appears that the acrylamide intake by Flemish adolescents is of the same order as that in other developed countries. Differences in absolute figures are probably due to the fact that different subpopulations were included and that different methodologies were applied, e.g., different food consumption questionnaires, different models, and probably the inclusion of more food items because of the extrapolation of analytical data among related food items. As in other studies (Sweden, Norway, the Netherlands) the most important solid food sources are French fries and related potato products, the consumption of which may be higher in our country than in others (Dybing & Sanner, 2003; Konings *et al*, 2003; Svensson *et al*, 2003). Bread contains a low amount of acrylamide but is the most important contributor in the lower percentiles. This could be explained by the relatively large daily consumption of this food group in Belgium. Coffee contributes considerably in the higher percentiles of the acrylamide intake. Compared to an adult population, however, the coffee consumption in our adolescents remains rather low; in an adult setting coffee would become more important. Swedish and Norwegian studies indeed revealed the high contribution of coffee in the intake of acrylamide by adult populations (Dybing & Sanner, 2003; Svensson *et al*, 2003).

It must be emphasized that, for several reasons, the exposure assessment presented here has several limitations. The exposure assessment is still based on a limited number of analytical measurements in a limited number of food items and samples. This is only partially remediated by the extrapolation of analytical results to strongly related food items that were not analysed for acrylamide. Based on the findings of Konings and co-workers, the impact of this extrapolation would be rather small (Konings *et al*, 2003). The choice to introduce into the model a value of one third of the limit of quantitation, for concentrations below the limit of quantitation, might lead to an under or over estimation of the acrylamide intake. French fries, which are important contributors to the total intake, are mainly processed at home at variable conditions and it is known that the acrylamide content is highly affected by frying temperature and frying time (Tareke *et al*, 2002). No analyses, however, were carried out on home prepared food and no uncertainties were introduced in the model to take this into account. Finally, the issue of under-reporting can not be neglected. Several studies have shown that under-reporters have a specific pattern of under-recording (Heitmann & Lissner, 1995; Lafay *et al*, 2000). Snack-type foods are preferentially forgotten in food questionnaires and food items rich in fat and/or carbohydrates (such as butter, French fries, sugars and confectionery, cakes and pastries) are reported less frequently and/or in smaller quantities than actually consumed. Due to the lack of complementary data (e.g., the effect of home processing) and the unavailability of a valid indicator to detect adolescent under reporters, it remains difficult to predict the total impact of all these factors on the intake assessment; it is almost certain that the real intake in most studies, as in ours, is higher than calculated.

For risk assessment purposes, the length of time over which dietary samples are to be collected is several consecutive days at multiple intervals of months, seasons and years (Kroes *et al*, 2002). In the present study, the only existing, available food consumption data-set, which was collected for other purposes, is used. The population was followed during 7 days and included all foods and beverages consumed at meals and in between, in quantified amounts. In general, it is accepted that a 7-day dietary record represents a habitual intake. However, in exposure assessment no consensus is achieved to the time frame to be used in the assessment of intake of food chemicals (Kroes *et al*, 2002). On the other hand, it was found that the diet history method is probably the best choice, followed by dietary records, to estimate exposure to food additives (Lowik, 1996). Nevertheless, various strategies for exposure calculation can be achieved depending on the nature of the available data; this is extensively described by Kroes *et al*. (2002). In the current study, a one-dimensional Monte Carlo has been executed. Individual food consumption distributions and food contamination distributions were used in the model. In the current method, the information on the input variability is passed on through the model to the output.

A quantitative estimation of the risk for adverse health effects in our population, on the basis of the estimated intake of acrylamide and health based exposure limits (oral reference doses), remains fraught with uncertainty. Indeed reference doses calculated for non-carcinogenic endpoints predict that intakes below these will not be accompanied by appreciable toxicity in man. Intakes slightly above these reference limits may be accompanied by adverse health effects, but quantitative figures are nearly impossible to estimate. An estimation of the risk for neurotoxic effects in our population heavily depends on the choice of the reference dose, 5 µg/kg bw/d or 0.2 µg/kg bw/d, depending on the reference experiment and assessment factors chosen (see methodology). Accordingly, no or small, undefined neurotoxic effects would be predicted at the estimated intake levels. It seems rather unlikely that even a detailed, controlled epidemiological study performed in the high intake group might be able to detect neuronal effects that can be undeniably attributed to acrylamide intake via food. Neurotoxicity has been observed in occupational studies (Hagmar *et al*, 2001; He *et al*, 1989; Marsh *et al*, 1999) but exposure was almost certainly substantially higher.

A similar caution should be applied when deducing extra-cancer numbers in our population as a result of the estimated acrylamide intakes and its CSF. As shown above, CSFs may be quite different depending on the data used and procedure followed. Furthermore, in the LMS approach the CSF 95th confidence limit is calculated according to a worst case approach. The actual cancer risk in man may be much lower or even zero (Crump, 1996; Lovell & Thomas, 1996). The LMS model (US-EPA) was indeed developed for regulatory purposes and not to predict cancer numbers in a particular situation (Crump, 1996).

Until now, epidemiological studies found no association between consumption of foods containing acrylamide and cancer risk (Erdreich & Friedman, 2004; Mucci *et al*, 2003; Mucci *et al*, 2004; Pelucchi *et al*, 2003). However, epidemiological studies have limited power to detect small increases in tumour incidence. Negative epidemiological studies may therefore provide an upper-bound to possible carcinogenic effects, rather than proof that no such effects exist (Food and Agricultural Organization / World Health Organization, 2002). However, Granath and Tornqvist (2003) concluded that acrylamide can contribute approximately 1% of the lifetime cancer risk, considering that a large fraction of all cancers has been attributed to dietary factors (American Cancer Society, 1999; Granath & Tornqvist, 2003).

Biomarkers of acrylamide exposure have been reported and estimated a background level (non-smoker) of 1.43 μg/kg bw/d (assuming a body weight of 70kg) (Svensson *et al*, 2003). Based on our findings and observations in the literature, the estimated dietary intake cannot explain the overall acrylamide exposure. Non-food acrylamide exposures may be substantial for some populations (Food and Agricultural Organization / World Health Organization, 2002). Other sources of acrylamide are cosmetics, drinking water, packaging materials and a possible endogenous formation in the body and also cigarette smoke (active and passive) and occupational exposure (European Commission, 2002b). Nevertheless, a reduction of acrylamide content in food could still contribute to a decrease of total acrylamide exposure, certainly at the higher percentiles of intake, supposing that all other intermediate factors are kept constantly.

Strategies to reduce the acrylamide content of food have been proposed by the European Commission after a workshop with the member states and stakeholder organisations in October 2003 (European Commission, 2003a), by Friedman (2003) and at the Acrylamide in Food Workshop (JIFSAN/ NCFST).

Meanwhile, because of undefined, although quite low, risks for neurotoxic effects and carcinogenic potency of acrylamide, its intake should be as low as possibly achievable. People should be advised to avoid excessive frying or baking, especially with regard to potato products.

7

HOW TO MEASURE DIETARY INTAKE AND FOOD HABITS IN ADOLESCENCE: THE EUROPEAN PERSPECTIVE

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Abstract

Aim: This paper deals with some methodological aspects of data collection in the context of measuring dietary intake in individuals in their adolescence life stage.

Method: Experiences from three partners of the HELENA project in dietary intake measurement in children and adolescents are presented in this paper with emphasis on characteristics of under-reporting, long-term diet measurement and food patterns (Dortmund DONALD group), influences of survey duration on under-reporting (Ghent group) and meal habits (Spanish AVENA group).

Results: Under-reporters in the DONALD Study, particularly female adolescents, had a significantly higher body mass index (BMI) than non-under-reporters; BMI could not be explained by different long-term dietary patterns during childhood and adolescence clustered according to fat consumption; consumers of fast food had higher BMI values than nonconsumers. In the Ghent experience, the decline in population mean energy intake as calculated over selected clusters of days is 184 kcal (6.5%) in boys and 116 (5.6%) in girls; the cluster of 1 recording day and the cluster of 3 recording days were not significantly different but they were both significantly different from the 7-day cluster; no significant interaction was observed between the effect of time and BMI. In the AVENA Study, the percentage of adolescents skipping breakfast was higher in females (8.6%) than in males (3.5%, $P<0.001$); higher BMI values were observed in those skipping breakfast than in those not skipping breakfast, but differences were statistically significant in males at 15 y and in females at 14 and 17 y; adolescents avoiding some food groups for breakfast had higher BMI values (carbohydrates, fruits and pastries in males and milk, fruits and pastries in females).

Conclusion: Dietary and nutrient intake data in the HELENA project will be obtained by means of repeated 24-h dietary recalls. Data from HELENA might be a basis for developing complex approaches like Healthy Eating Indices.

Introduction

Evidence that the nutrition-related risk factors for chronic diseases start in early childhood and adolescence is growing more and more. This has led to increasing interest in studying the adolescent population, which has been much less studied in former years than other population groups. Adolescence is a crucial period in life and implies multiple physiological and psychological changes that affect nutritional needs and habits. Adolescents have particular food choices and meal habits compared to younger children and adults. They differ in irregular eating patterns, frequent snacking and frequent skipping of meals, particularly breakfast. These facts render the collection of accurate dietary intake data even more difficult than in other age groups.

The HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescents) Study, supported by the E.U. 6th Framework Programme, includes cross-sectional, crossover and pilot community intervention multi-centre studies. One of the main objectives of the project is to obtain reliable and comparable data of a representative sample of European adolescents, concerning dietary intake and food habits. Therefore, there is a need to establish an adequate data recording methodology.

The prevalence of childhood overweight and obesity has increased in the majority of the countries in the last decades (Moreno *et al*, 2000a; Moreno *et al*, 2005; Ogden *et al*, 2002). Obesity is not a single disease, but a complex multi-factorial condition involving environmental and genetic factors. Among the environmental factors, diet appears to be an important contributor to the development of obesity. The ability for an accurate measurement of dietary patterns and food and nutrient intake in children and adolescents is an essential instrument in the battle against the currently observed disruption of body weight regulation in large parts of the population.

Very recently, a systematic review of surveys of dietary intake and status in children and adolescents conducted in Europe has been carried out by an ILSI Europe Task Force (Lambert *et al*, 2004). Surveys that satisfied a defined set of criteria (published, based on individual intakes, post-1987, adequate information provided to enable its quality to be assessed, small age bands, data for sexes separated above 12 y, sample size over 25 and subjects representative of the population) were selected for further analysis. A total of 79 surveys from 23 countries were included and, from them, data on energy, protein, fats, carbohydrates, alcohol, vitamins, minerals and trace elements were collected and tabulated. Data on energy, protein, total fat and carbohydrate were given in a large number of surveys, but information was very limited for some micronutrients. No surveys gave information on fluid, intake and insufficient data were given on food patterns. A variety of collection methods were used, there was no consistency in the ages of children surveyed or the age cut-off points, but most surveys gave data for males and females separately at all ages. Just under half of the surveys were nationally representative and most of the remainder were regional. Males had higher energy intakes (EIs) than females; EI increased with age but levelled off in adolescent girls. Intakes of other nutrients were generally related to EIs. Some north–south geographical trends were noted in fat and carbohydrate intakes, but these were not apparent for other nutrients. Some other trends between countries were noted, but there were also wide variations within countries. The main conclusion was the need for harmonisation and standardisation of the methods of nutrition surveys in Europe.

Designing an instrument to evaluate an adolescent's eating habits requires addressing not only the typical requirements for a diet-assessment tool but also the unique concerns of the adolescent population. A limited number of dietary assessment instruments that are specifically designed for adolescents have been found to be reproducible and validated. There is a demand for short, easily administered, inexpensive, accurate instruments that can be used in a broad range of adolescent subpopulations (Rockett *et al*, 2003).

This paper deals with some methodological aspects of data collection in the context of measuring dietary intake in individuals in their adolescence life stage. In general, adolescents are, at the group level, expected to be more prone to reporting bias as part of their general tendency towards a more immature behaviour, and some reluctance in participating in initiatives taken by adults. For adolescents that are confronted with body weight problems, the social pressure concerning eating (both with respect to the type of food they are eating and the amounts of food) are expected to add to the already mentioned problems.

Experiences from three partners of the HELENA project in dietary intake measurement in children and adolescents are presented in this paper, with an emphasis on characteristics of under-reporting, long-term diet measurement and food patterns (Dortmund DONALD group), influences of survey duration on under-reporting (Ghent group) and meal habits (Spanish AVENA group).

The Dortmund Nutritional and Anthropometric Longitudinally Designed (DONALD) Study

The DONALD Study, an ongoing mixed cohort study that started in 1985, covers the age range of 0.25–18 y in healthy infants, children and adolescents. In this study, repeated 3 day weighed food records were collected together with body weight and height measurements in a longitudinal design with an identical methodology over the full age range since the start of the study (Kroke *et al*, 2004). Among others, these data give the unique opportunity to examine age effects on the nutritional and preventive quality of the diet and on the validity of dietary intake measurements as well as associations of dietary intake and body weight (obesity).

Characteristics of under-reporting

In the DONALD Study, age effects were found for the responsibility of the family members for the diet records. While some children from the age of 7 y assisted their parents in recording, 80% of the 10–12 y olds already helped. In the adolescents, totally self-reliant records were kept by 20% (30%) of the males (females) at the age of 13–14 y and by 70% (90%) above 15 y of age (Kersting *et al*, 1998b).

In epidemiological studies, the problem of under-reporting can be evaluated by a statistical method, proposed by Goldberg *et al* (1991), relating measured EI to individual (predicted) basal metabolic rate (BMR) in a ratio EI/BMR (see also Ghent group). However, ‘Cut-off 2’ values for plausible EI/BMR ratios calculated for adults are not per se adequate for younger age groups.

Therefore, Cut-off 2 values were recalculated for children and adolescents based on specific intra-individual variation of EI (Sichert-Hellert *et al*, 1998).

Under-reporting (% of not plausible low EI) was then identified as age and sex specific in the DONALD Study and (except the 14–18-y-old males) lower for the recalculated than for the original Cut-off 2 values particularly for females, with 1% lowest in the 1–5 y olds, 2–3% in the 6–13 y olds, but manifestly higher in the adolescent groups and obviously dependent on sex, with 12% for males and 20% for females. Using the Cut-off 2 values proposed for adults would have increased numbers of not plausible records in female adolescents up to 30%.

Under-reporters in the DONALD Study, particularly female adolescents, had a significantly higher BMI than non-under-reporters (Sichert-Hellert *et al*, 1998). High BMI values were identified as a significant risk factor for under-reporting by other authors, too (Bandini *et al*, 1990; Bratteby *et al*, 1998; Champagne *et al*, 1998; Livingstone *et al*, 1992; Livingstone & Robson, 2000; Price *et al*, 1997). Particularly, female adolescent under-reporters compared with non-under-reporters showed different meal habits: fewer meals (about one meal less per day), less energy intake per meal (about 25% less), more often warm meals, a shorter time span between the first and the last meal per day. They also had different nutrient patterns related to EI: higher intakes of water, protein, fibre, sodium, iron, niacin and zinc and lower intakes of added sugars than non-under-reporters. It can be speculated that these findings point to specific omissions of sweet and/or snack foods in subjects who under-report their EI. It is well known that girls are more concerned about their body image (especially weight) than boys (Andersen *et al*, 1995; Moore, 1993) and dieting accompanied by a fear of obesity is very common among adolescent girls (Flynn, 1997; Maloney *et al*, 1989). Even females with normal weight appear much more likely to generate records with no valid food intake data (Mela & Aaron, 1997). They may use record keeping consciously or subconsciously to assist in losing weight. Thus, the records may be valid – but do not reflect the subject's usual intake.

Long-term nutrient intake and body weight

Results of studies examining associations between dietary composition and obesity in adolescence are conflicting. A cross-sectional study in adolescents (Garaulet *et al*, 2000) (but more studies in children) found a positive association between fat intake and anthropometric measurements. However, studies examining long-term nutrition and body fatness mostly found no or only minor effects (Berkey *et al*, 2000; Cavadini *et al*, 2000; Magarey *et al*, 2001; Troiano *et al*, 2000), including the DONALD Study (Remer *et al*, 2002).

In the DONALD Study, a new-developed cluster method was used to investigate nutrient intake and anthropometric measures in individuals, longitudinally (Alexy *et al*, 2004; Alexy *et al*, 2005). For this evaluation, 228 participants aged 2–18 y with at least 10 dietary records (repeated yearly) were available. To control for age and gender effects, dietary and anthropometric data were transformed: EI were expressed per kilogram body weight, per gram total food intake and per estimated BMR; macronutrients were calculated as percentage of EI (E%); BMI was recalculated as standard deviation scores (SDS) of BMI, according to IOTF reference standard (Cole *et al*, 2000). Clustering was based on fat intake (E%).

Four typical clusters (C, M, H, L) differing mainly according to intra-individual mean fat intakes and intra-individual SD of the repeated fat intake measurements were identified (1) Constant Cluster where fat intakes mostly ranged between median and third quartile, (2) Medium Cluster where fat intakes were similar to Constant Cluster, but, with a higher intra-individual SD, (3) High Cluster where more than 50% of subjects had fat intakes over the third quartile and (4) Low Cluster where most subjects had fat intakes lower than the 1st quartile. Mean EI did not differ between clusters, but energy density and EI/BMR did. Subjects with fat intakes lower than the first quartile (Low Cluster) had almost the highest BMI–SDS scores and those of the Constant Cluster (with quite high fat intakes), almost the lowest scores (Figure 7.1). In total, this statistical evaluation showed that BMI could not be explained by different long-term dietary patterns during childhood and adolescence clustered according to fat consumption.

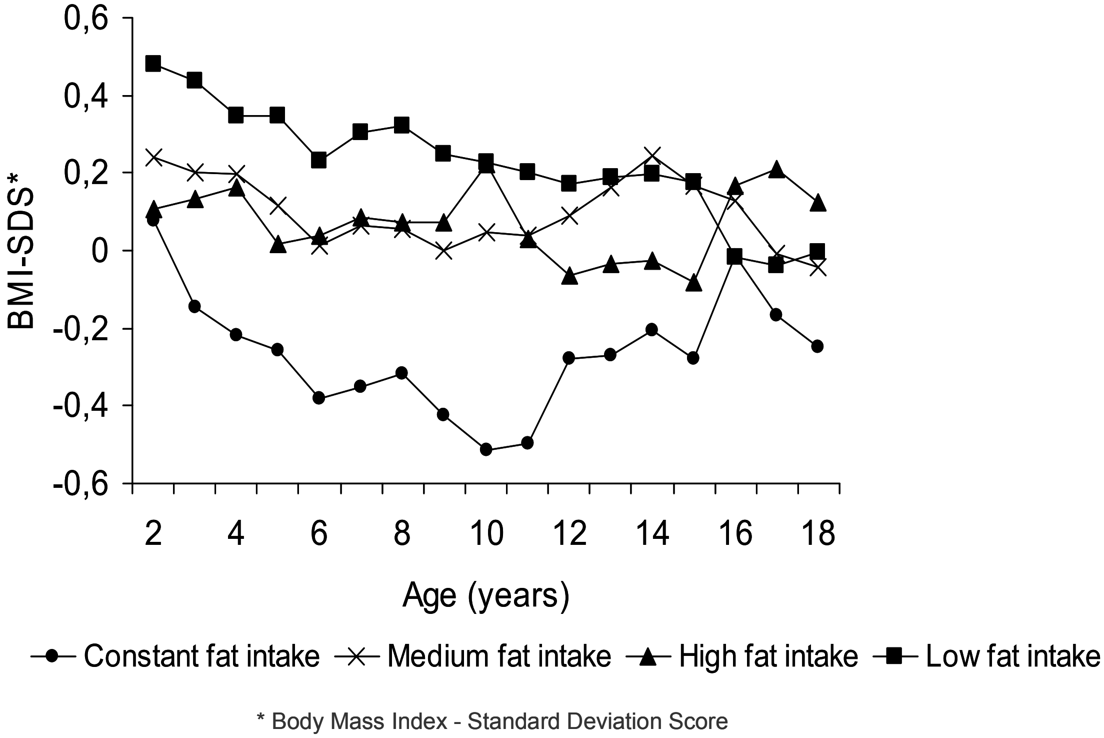

Figure 7.1: Differences in BMI–SDS scores according to fat consumption cluster in the DONALD Study.

Fast food consumption patterns

In the cross-sectional and longitudinal data analysis of the DONALD Study, no obvious differences between children and adolescents in consumption patterns for basic foods, for example bread, vegetables and milk, were observed (Alexy *et al*, 2001). However, this was not the case for modern 'lifestyle' foods such as soft drinks and fast food that are both discussed to be associated with an increased risk for obesity in children and adolescents. In a recent evaluation, fast food consumption patterns between 1986 and 2003 in 1–18 y olds were examined. Fast food dishes were defined as warm dishes eaten in or taken away from fast food restaurants or other places, for example pizzerias, cafeterias and soup kitchens. Soft drinks bought and consumed together with fast food dishes were also evaluated as 'fast food'. Fast food dishes were grouped into 'Burger' (containing meat), other 'meat-based fast food' (e.g., gyros, doener, fried sausage), 'fish' (fried), 'pizza', 'potatoes' (e.g., French fries) and 'others' (without meat, e.g., crepes, fried mushrooms). Beverages were grouped according to the content of caffeine (caffeinated, non-caffeinated) and sugars (non-sugar-containing 'light soft drinks'; sugar-containing 'other soft drinks'). Subjects reporting at least one fast food dish or soft drink within a 3-day record were defined as consumers and those reporting no fast food dish or soft drink as non-consumers.

Frequency of consumption of fast food and soft drinks increased with age. Also, consumption patterns changed with age so that adolescents preferred high caloric menus (fast food dishes together with soft drinks) more than children (Figure 7.2a). With age, preferences increased for 'modern' fast food items like pizza and burger and decreased for classic fish and meat-based fast food (Figure 7.2b). There were no significant differences in food patterns according to gender in the different age groups studied here (Sichert-Hellert & Kersting, 2005).

Interestingly, and in contrast to other studies from the USA (Paeratakul *et al*, 2003), an influence of fast food consumption on BMI was found in the DONALD Study: consumers of fast food had higher BMI values than non-consumers (Alexy *et al*, 2001). Probably, food intake data based on measured consumption of various types of fast food including soft drinks is a stronger predictor of body weight than questionnaires addressing fast food restaurant visits.

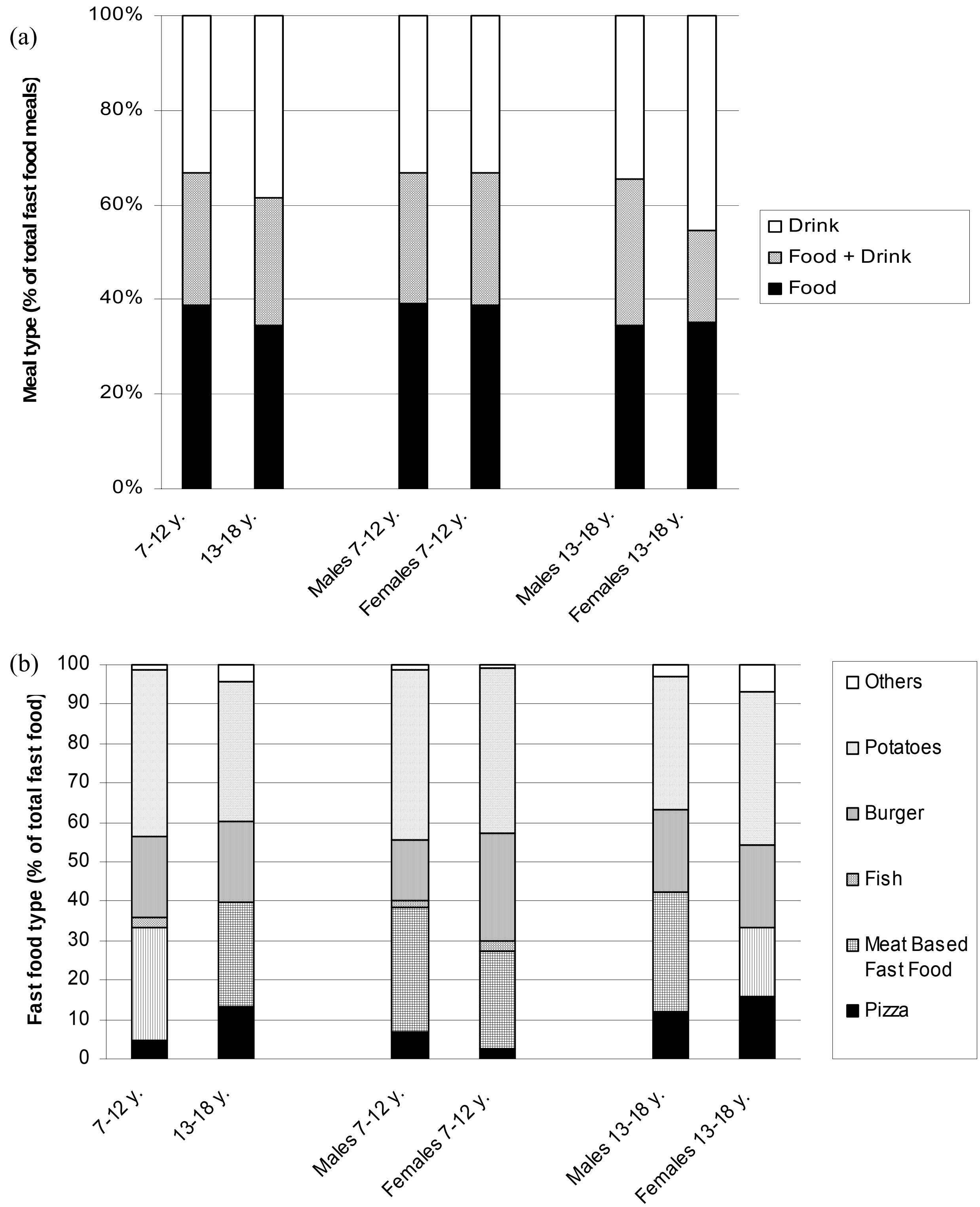

Figure 7.2: Preferences for fast food meal types (a) and preferences of fast food dishes (b) according to age and gender in the DONALD Study.

The Ghent experience

In 1997, a dietary survey was carried out among adolescents from the region of Ghent in Belgium, as part of an international collaborative project on methodological issues regarding dietary assessment (Lambe *et al*, 2000b). The target population was defined as adolescents aged 13–18 y attending schools in the city of Ghent in the northern Dutch-speaking part of Belgium.

The design and methodology of this survey have been described in detail elsewhere (Matthys *et al*, 2003). In brief, 656 students from 48 classes in five schools were selected. Non-eligible students (N=91) were removed from further enquiries as these individuals either were on long sickness leaves or had moved to other schools. Of these 565 eligible students, 411 individuals (72.7%) were actually willing to participate.

Dietary assessment was carried out on the basis of a 7-(consecutive) day estimated food record method, using a semi-structured diary. Individuals' heights and weights were measured according to the standardised method as described in WHO, Technical Report Series 854 (World Health Organization, 1995). Data on measured heights and weights were completed in the same period (within 1 week) as the dietary diary.

The data from the 7-day diary have been analysed according to two distinct approaches in order to examine the dimension of time in individuals' reporting behaviour. In a first approach, the 7 days were considered independently from each other in studying trends. In the second approach, the 7-day record was categorised into three clusters. The first cluster was set equal to the first reporting day, the second cluster consisted of the three first reporting days and the third cluster was defined as the overall period of the 7 days. For each cluster, intakes were calculated on individual level as the mean of the days under consideration.

As mentioned earlier (see the DONALD Study section) a comparison of EI with estimated BMR can be used to calculate the number of respondents in a dietary survey who might be under-reporting their EI (Goldberg *et al*, 1991). For individuals in a non-dieting population, it is suggested that a ratio between EI and BMR of less than 1.35 (Cut-off 1) is unlikely to reflect habitual intake. In order to detect if the reported EI is a plausible measure of the actual diet during the measurement period, a second cut-off value (Cut-off 2) was introduced. The derivation of Cut-off 2 is based on the assumption of energy balance and takes into account several parameters (Goldberg *et al*, 1991). The calculation of Cut-off 2 in this study was carried out under the following conditions: data on individual level, number of days per subject, estimated values for BMR taken from Schofield equations (Schofield *et al*, 1985) and the lower limit of the 95% confidence interval. For the results based on 1 recording day, the value for the second cut-off was set at 0.9, for the cluster of 3 recording days the value was set at 1.0 and for the entire 7 days, the cut-off of 1.1 was used.

The study population is assumed to be a good representation of the overall target population of adolescents in the region of Ghent (Matthys *et al*, 2003). There were however substantially more girls than boys in the sample and there also was a slight under-representation of individuals from lower educational school segments. Among the boys, a small number of overweight adolescents were observed (7%), while among the girls almost 15% was defined as overweight. The mean (SD) ratio of EI/BMR was 1.6 (0.31) in boys and 1.4 (0.33) in girls.

Figure 7.3 shows the evolution of the mean EI in the adolescent population during the 7 consecutive days of the diary and the derived mean intakes for day 1, the first 3 days and the overall 7-day recording period. In both boys and girls, there is a gradual decrease in the mean population EI from a mean value of 2836 on day 1 to 2491 kcal on day 7 in boys and from 2086 to 1738 kcal, in girls. The 1st and 2nd recording day were not significantly different from each other but were significantly different from all other days. The resulting decline in population mean EI as calculated over selected clusters of days is 184 kcal (6.5%) in boys and 116 (5.6%) in girls. The cluster of 1 recording day and the cluster of 3 recording days were not significantly different but they were both significantly different from the 7-day cluster.

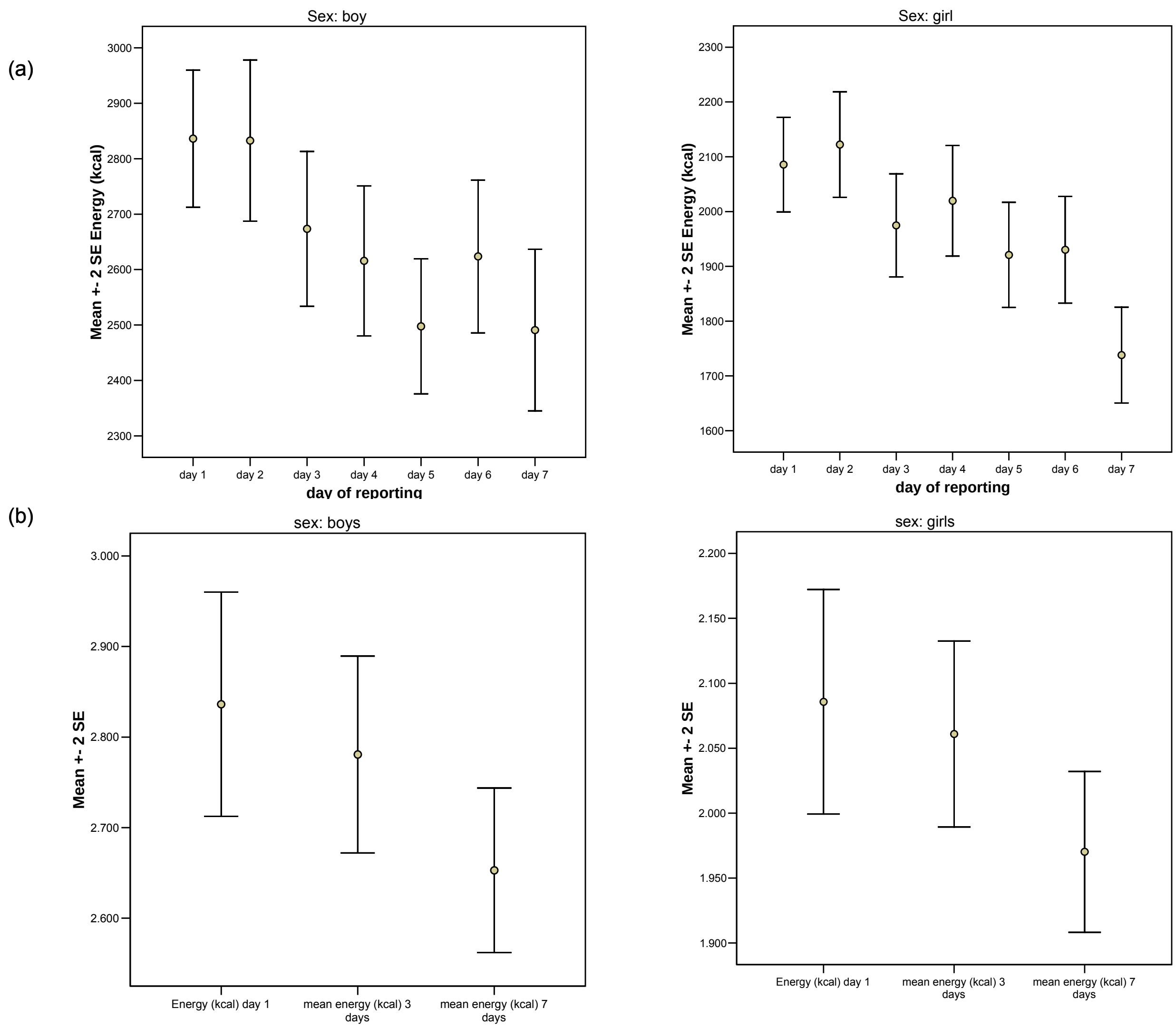

Figure 7.3: The evolution of the mean (± *SE*) energy intake over the seven consecutive days of the diary (a) and the derived mean intakes over respectively a one day, a three day and a seven day recording period (b) in boys and girls.

In a bivariate model including an indicator of body fatness, that is, BMI expressed as percentage of the percentile cut-off points according to Cole's methodology (Cole *et al*, 2000), no significant interaction was observed between the effect of time and this indicator of body fatness, suggesting that overweight individuals and normal weight individuals in this age group present similar types of time-dependent reporting bias for EI.

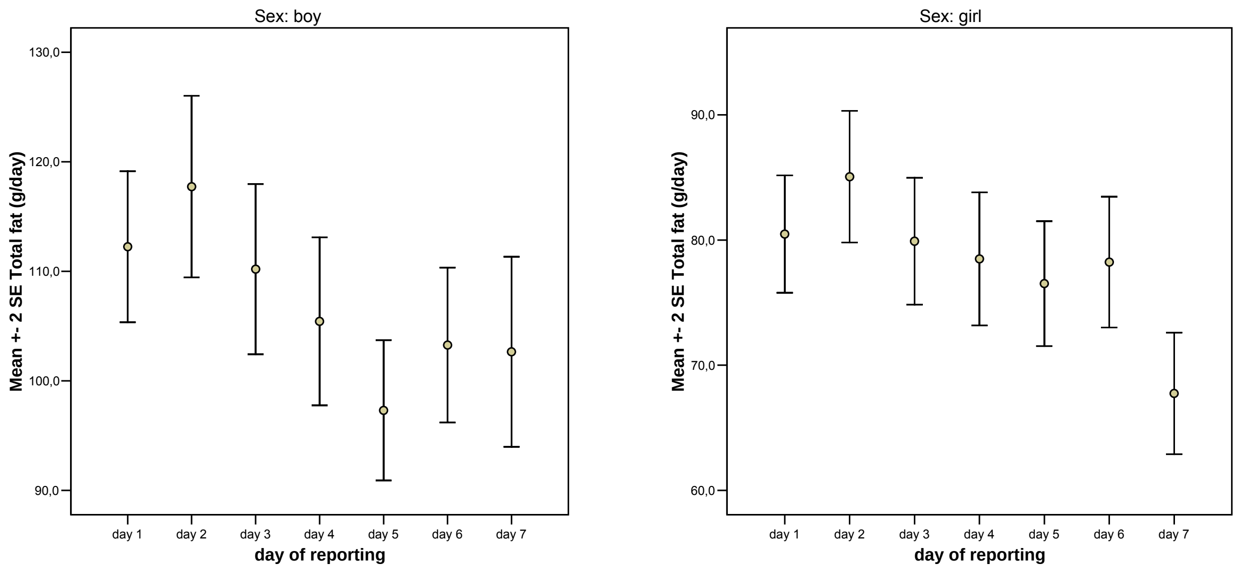

Figure 7.4: The evolution of the mean (±*SE*) fat intake over the 7 consecutive days of the diary expressed as g/day in boys and girls.

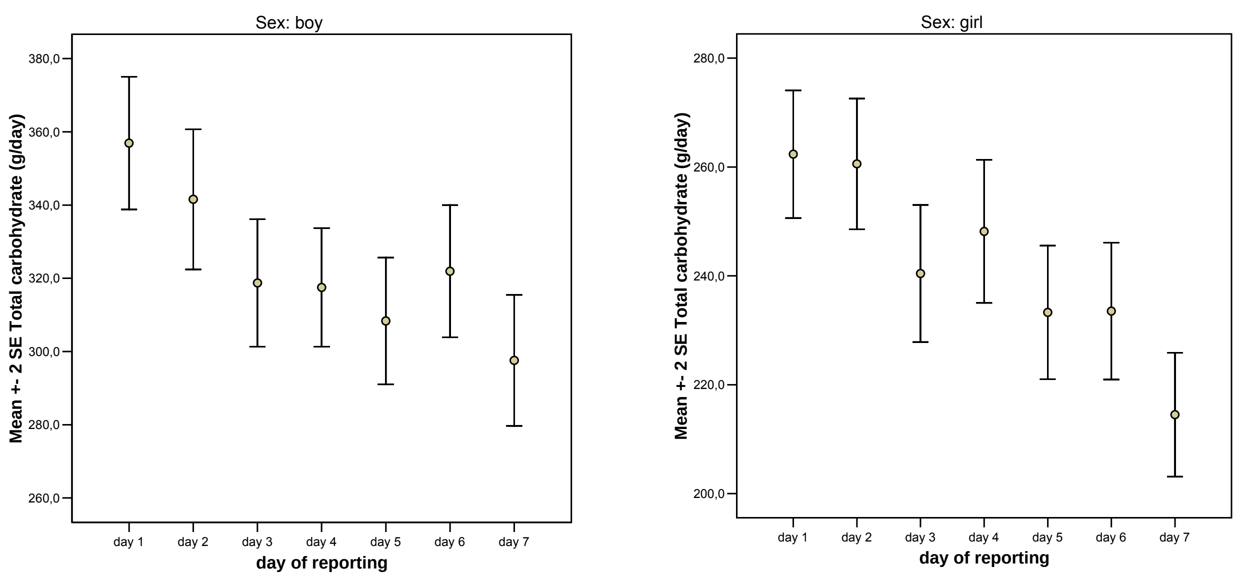

Figure 7.5: The evolution of the mean (±*SE*) carbohydrate intake over the 7 consecutive days of the diary expressed as g/day in boys and girls.

Figures 7.4 and 7.5 show analogous graphical presentation for total fat intake and for total carbohydrate intake, expressed as absolute intake for boys and girls separately. Intake of fat and carbohydrate expressed as absolute values decreases gradually over the 7-day recording period. The difference between mean intakes on days 1 and 7 amounts to 9.5 g/day for fat and 59.3 g/day for carbohydrate in boys and to 12.8 g/day for fat and 47.8 g/day for carbohydrate in girls. Expressed as a proportion of the absolute intake, these differences are somewhat lower for fat than to carbohydrates, suggesting that reporting bias for foods with high fat content is somewhat less pronounced. Fat and carbohydrate intake relative to total EI shows a somewhat different overall picture. Both for fat and carbohydrate, the mean proportional EI remains relatively stable, in view of the declining EI (data not shown).

Tables 7.1 and 7.2 show the changes in the estimated proportions of individuals that are under-reporting according to the criteria described before. Based on the 7 consecutive days, the proportion of adolescents below the cut-off of 0.9 increased from 7.9% on the 1st recording day to 19.9% on the 7th day. Comparing the clusters of days (1/3/7) the proportion of subjects who were defined as under-reporters (using the appropriate cut-offs for each category, see above) increases from 7.9% in the 1-day cluster to 15.5% in the 7-day cluster. It should be noted that these cut-off values of the EI/BMR ratio were based on calculations in adults. However, a recalculation for adolescents would not substantially change the conclusions regarding trends in under-reporting.

Table 7.1: The proportion of individuals that are underreporting (EI/BMR < 0.9) according to sex and recording day. The Ghent experience.

	Boys		Girls	
	EI/BMR		EI/BMR	
	< 0.9	>= 0.9	< 0.9	>= 0.9
day 1	3.1	96.9	10.8	89.2
day 2	3.1	96.9	10.8	89.2
day 3	6.2	93.8	15.1	84.9
day 4	7.8	92.2	16.0	84.0
day 5	9.3	90.7	18.9	81.1
day 6	10.1	89.9	20.3	79.7
day 7	9.3	90.7	26.4	73.6

Table 7.2: Proportion of individuals that are underreporting according to sex and cluster of recording days. The Ghent experience.

	Boys		Girls	
	Under-reporting	Normal reporting	Under-reporting	Normal reporting
Cluster of 1 day (EI/BMR < 0.9)	3.1	96.9	10.8	89.2
Cluster of 3 days (EI/BMR < 1.006)	3.9	96.1	14.2	85.8
Cluster of 7 days (EI/BMR < 1.1)	7.8	92.2	20.3	79.7

These findings suggest an important impact of survey duration on the reported intake of energy, fat and carbohydrates. The observed decline in reported population mean energy and energy yielding macronutrients over the 7-day survey period is compatible with the increasing proportion of under-reporters, although theoretically these two phenomena can be quite independent from each other. However, the stability of the confidence intervals strongly suggests that the declining trend affects the population as a whole and that the shift in the population distribution gradually 'pushes' a higher proportion of the population across the 'under-reporting edge'. This observation also raises the question of whether respondents are – on population level – reporting normally during the first 2 days or are perhaps over-reporting during the first days and then gradually return to adequate reporting. The latter scenario is however less plausible in view of the proportion of under-reporters detected by the cut-offs. However, the reality underlying these observations could be rather more complicated than described here. Overall, these findings could be compatible with a hypothetical participants' motivation curve, falling off with increasing number of days of data collection, especially if these days are consecutive (Gersovitz *et al*, 1978).

The different clusters of reporting days in our study show that the clusters of 1 and 3 days do not show significant differences in mean intake of macronutrients. The percentage of under-reporters within this time window also remains stable around 10% for all adolescents. For many purposes in the context of studying diet-related diseases, it has been recommended in the literature that more than one record per individual be collected (Guenther *et al*, 1997). Different studies have shown that 3 record days were better than 1-day estimates of individual intake (Freudenheim *et al*, 1987). Lambe *et al* found that 3 days provided a much better reflection of more long-term intakes of food items than 1 day (Lambe *et al*, 2000a). The number of records is described to be at least two, assuming that the sample size is large enough (Hoffmann *et al*, 2002). Different researchers recommended using non-consecutive days when multiple records were used (Hartman *et al*, 1990; Hoffmann *et al*, 2002; Tarasuk & Beaton, 1992).

The Alimentación y Valoración del Estado Nutricional en Adolescentes (AVENA) Study

The AVENA Study is a Spanish cross-sectional multi-centre survey carried out between 2000 and 2002. The main objective of the AVENA Study was to obtain data about health status, dietary and behaviour habits and the nutritional-metabolic situation of a representative sample of adolescents that were lacking at the time the study was planned. Specifically, the following magnitudes have been studied: (a) dietary intake, food habits and nutrition knowledge; (b) daily physical activity and personal approach; (c) physical condition; (d) anthropometry and body composition; (e) haematological and biochemical study; (f) genotypic profile of cardiovascular risk factors; (g) immune function profile related to nutritional status and (h) psychological profile (Gonzalez-Gross *et al*, 2003).

The AVENA Study has been possible due to the coordinated activity of five research groups in five Spanish cities (Granada, Madrid, Murcia, Santander and Zaragoza). Strict standardisation and harmonisation of the field work and the centralised analysis of blood samples and evaluation of questionnaires have tried to avoid from the beginning the huge amount of confusing variables that appear when data from isolated studies are compared.

A fundamental component of a healthy diet is to eat a balanced breakfast, which is important for nutritional adequacy. A good breakfast can contribute to a healthy diet rich in carbohydrates and micronutrients (Aranceta *et al*, 2001; Siega-Riz *et al*, 2000). In fact, having an adequate breakfast has been related to both physical and cognitive function and better performance at school in children and adolescents. The breakfast habits have changed in the course of time and the number of breakfast skippers has increased during the last 30 y. Especially, female and older adolescents tend to omit the morning meal (Siega-Riz *et al*, 1998). Various reasons for skipping breakfast such as lack of time or not being hungry in the morning can be observed (Reddan *et al*, 2002). Cho *et al* have also observed that some types of breakfast, like meat and eggs and breakfast skippers were associated with the highest BMI values (Cho *et al*, 2003).

For the results presented in this paper, a sample of 1282 adolescents (572 males, 710 females) aged 13 to 18.5 y from Santander, Zaragoza and Granada were analysed. The population was selected by means of a multiple-step, simple random sampling, taking into account first the location (Granada, Madrid, Santander, Zaragoza and Murcia) and then by random assignment of the schools within each city. Sample size was stratified by age and sex.

Breakfast habits were analysed by means of a specific question included in a full questionnaire. This form was specifically designed by the research team for the study and validated in the AVENA pilot study (Gonzalez-Gross *et al*, 2003). The question contained 12 alternatives for breakfast components, which were 10 foods that are typical of a Spanish breakfast, such as milk, toast, biscuits or fruit. One 'other-field' was included in which unlisted components could be itemised. Finally, participants could indicate that they had no breakfast at all. The task was to mark the components of one's own habitual breakfast. The 10 foods were divided into five food groups: milk (milk and cocoa), carbohydrates (toasts, granola and cereals), fruit (fruits and juices), pastries (biscuits and pastries) and coffee.

The percentage of adolescents skipping breakfast was higher in females (8.6%) than in males (3.5%, $P<0.001$). A marked age-effect on female breakfast skippers should be pointed out, as at age 13 y only 1.7% of the girls skipped breakfast and at age 17–18.5 y already 13.5% did ($P<0.01$). The proportion of adolescents consuming milk, carbohydrates, fruits and pastries was higher in males than in females (Figure 7.6). These differences by sex have also been observed in other studies. In studies from the USA (Morgan *et al*, 1986a) and Sweden (Hoglund *et al*, 1998; Sjoberg *et al*, 2003), there were more breakfast skippers among females than among males. These differences were even greater than in the AVENA Study. When we compared BMI mean levels between adolescents skipping and not skipping breakfast, in general, we observed higher BMI values in those skipping breakfast when compared with those not skipping breakfast, but differences were statistically significant in males at 15 y and in females at 14 and 17 y (Table 7.3). When we analysed BMI according to breakfast food consumption (Tables 7.4 and 7.5), we observed that adolescents who avoid some food groups for breakfast had higher BMI values. The results were statistically significant for carbohydrates (at ages 13, 14 and 17 y), fruits (at 13 y) and pastries (at 13 and 15 y) in males, and for milk (at 13 y), fruits (at 16 and 17 y) and pastries (at13 y) in females.

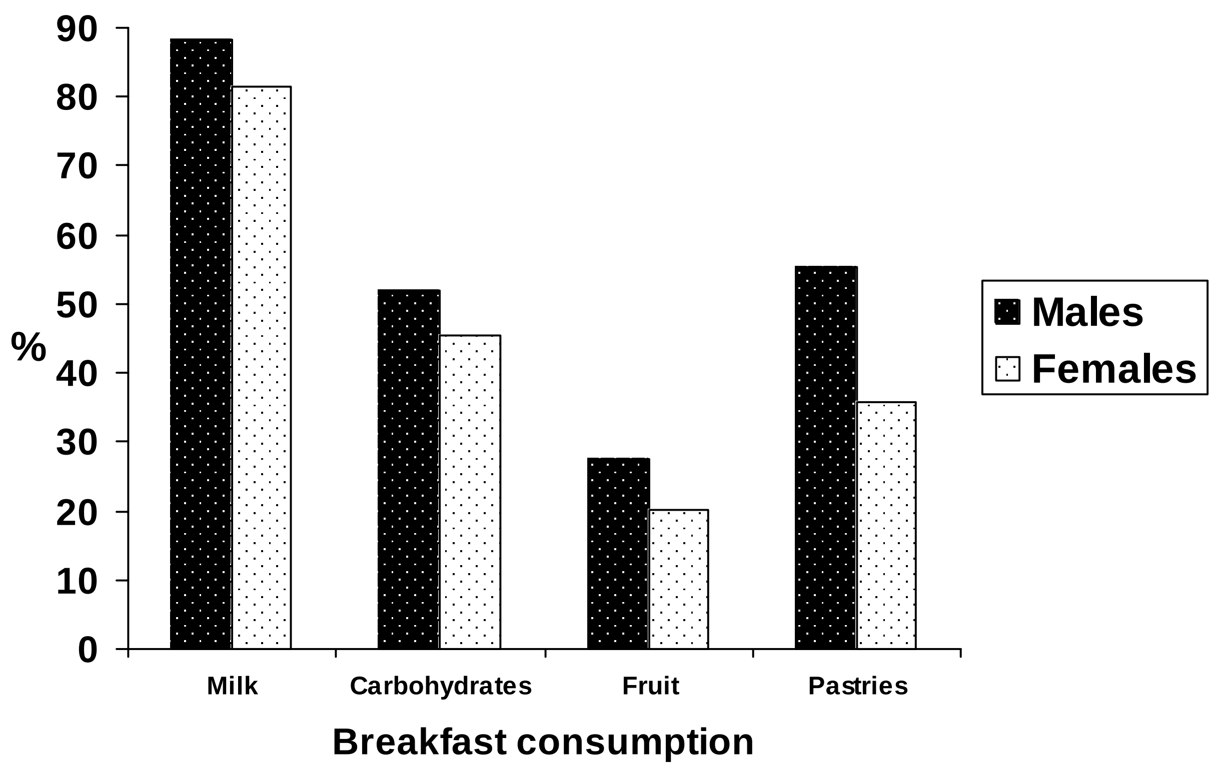

Figure 7.6: Breakfast patterns by gender in adolescents from the AVENA Study.

Table 7.3: Body mass index in Spanish adolescents skipping or not skipping breakfast. The AVENA Study

Age	Males		Females	
	Yes Mean (SD)	No Mean (SD)	Yes Mean (SD)	No Mean (SD)
13 years	-	-	-	-
14 years	24.07 (5.47)	21.53 (3.35)	23.46 (6.70)	21.21 (3.26)*
15 years	24.21 (7.28)	22.52 (3.56)*	22.64 (2.71)	21.40 (2.77)
16 years	22.44 (2.54)	21.87 (3.03)	22.63 (2.36)	21.63 (2.88)
17 years	21.56 (0.46)	22.84 (3.08)	23.11 (4.05)	21.60 (2.93)*

*P<0.05

We have not investigated the reasons for skipping breakfast, but other studies observed that the reasons were lack of time for the preparation and consumption and concerns about excess body weight (Bellisle *et al*, 1995; Ruxton & Kirk, 1997). However, there is a statistically significant influence of socio-economic status on breakfast habits, as the percentage of adolescents having an 'adequate' breakfast increases as the SES increases (from 11.2 to 27.6%; P<0.05).

In coincidence with our data, an inverse relationship has been found between BMI and breakfast consumption in other studies (Bellisle *et al*, 1988; Gibson & O'Sullivan, 1995; Ortega *et al*, 1998b; Summerbell *et al*, 1996). Breakfast eaters tend to have a lower BMI than breakfast skippers (Gibson & O'Sullivan, 1995), and obese individuals are more likely to skip breakfast or consume less energy at breakfast (Bellisle *et al*, 1988; Ortega *et al*, 1998b). Breakfast skipping can lead to overeating later in the day (Martin *et al*, 2000). In contrast, eating breakfast is associated with increased eating frequency and this may in turn promote less efficient energy utilisation by increasing dietary-induced thermogenesis, leading to a lower BMI (Drummond *et al*, 1996). Eating some foods for breakfast, like carbohydrates, seems to be associated with a significantly lower BMI than skipping breakfast or eating other food items (Cho *et al*, 2003) as we observed in our adolescents.

Table 7.4: Body mass index by breakfast food consumption in male adolescents. The AVENA Study.

Age	Milk		Carbohydrates		Fruit		Pastries	
	Yes Mean (SD)	No Mean (SD)	Yes Mean (SD)	No Mean (SD)	Yes Mean (SD)	No Mean (SD)	Yes Mean (SD)	No Mean (SD)
13 years	20.33 (3.54)	19.64 (4.32)	19.84 (3.35)	21.06 (3.87)*	19.51 (2.83)	20.52 (3.76)*	19.72 (2.76)	20.86 (4.21)***
14 years	21.55 (3.72)	22.71 (5.24)	20.86 (3.36)	22.65 (4.25)*	23.25 (4.40)	21.14 (3.56)	22.09 (4.14)	21.31 (3.63)
15 years	22.34 (3.53)	24.04 (4.11)	22.30 (3.69)	22.83 (3.58)	23.19 (4.32)	22.30 (3.31)	22.27 (3.06)	22.81 (4.08)*
16 years	21.98 (3.05)	21.39 (2.66)	22.02 (3.31)	21.76 (2.62)	21.40 (2.79)	22.08 (3.04)	21.64 (2.74)	22.33(3.28)
17 years	22.64 (2.90)	23.72 (3.71)	21.61 (2.14)	23.41 (3.25)*	23.26 (3.10)	22.51 (2.98)	22.74 (2.66)	22.89 (3.59)

*P<0.05, **P<0.01, ***P<0.001 when comparing Yes *vs*. No in the same age and pattern category.

Table 7.5: Body mass index by breakfast food consumption in female adolescents. The AVENA Study.

Age	Milk		Carbohydrates		Fruit		Pastries	
	Yes Mean (SD)	No Mean (SD)	Yes Mean (SD)	No Mean (SD)	Yes Mean (SD)	No Mean (SD)	Yes Mean (SD)	No Mean (SD)
13 years	21.15 (3.40)	23.37 (5.36)*	21.37 (3.69)	21.32 (3.63)	20.99 (2.51)	21.45 (3.90)	20.72 (2.37)	21.83 (4.34)**
14 years	21.11 (3.26)	22.55 (4.44)	21.24 (3.35)	21.34 (3.55)	21.82 (3.30)	21.20 (3.48)	20.70 (2.79)	21.63 (3.74)
15 years	21.41 (2.87)	21.96 (2.42)	21.30 (3.01)	21.75 (2.54)	21.89 (2.05)	21.42 (2.96)	21.15 (2.26)	21.75 (3.04)
16 years	21.71 (2.99)	21.67 (2.27)	21.89 (3.18)	21.55 (2.49)	20.82 (1.73)	21.96 (3.04)*	21.35 (2.49)	21.89 (3.02)
17 years	21.62 (2.96)	22.17 (3.43)	22.04 (2.96)	21.53 (3.16)	21.17 (2.49)	21.92 (3.22)*	21.38 (2.82)	21.91 (3.18)

*P<0.05, **P<0.01, ***P<0.001 when comparing Yes *vs*. No in the same age and pattern category.

Comments and conclusions

The relationship between diet and obesity should focus not only on energy and macronutrient intake, but also on dietary patterns. Traditionally, the focus has been on energy balance and percentage contribution of macronutrients, but the results are very controversial, especially for dietary fat and proteins (Moreno *et al*, 2000b). As a result of several shortcomings in traditional nutrient-based diet and disease analysis, the focus has shifted from this type of analysis to one describing food intake patterns (Nicklas *et al*, 2001). Such analysis takes into account the complex combination of foods in a diet. The effect of such food-based defined dietary patterns might be more closely related to obesity than a single nutrient or food. To describe dietary intake and food habits in overweight and obese individuals will be relevant not only in terms of causality of obesity, but also in terms of the knowledge and understanding of the eating behaviour with regard to body weight regulation in a modern affluent society.

In adults, several epidemiologic studies examined the association of dietary patterns and excessive body weight (Maskarinec *et al*, 2000; Newby *et al*, 2003; Togo *et al*, 2001). These food-based dietary patterns have been established on the basis of several statistical methodologies. Another approach to assessing an individual's diet is to score it with a set of criteria to produce a composite index of diet quality. A low Healthy Eating Index (HEI) was associated with overweight and obesity; there was a graded increase in the odds ratio of obesity across the HEI category after adjusting for age, gender, race/ethnicity, physical activity, smoking, alcohol use, income and education (Guo *et al*, 2004).

Assessment of dietary intake faces many problems, both related to the true nature of variation in an individual's diet and to a number of potential sources of error linked to the measurement instrument and to the reporting subject. Depending on the type of research and the dietary assessment instruments chosen accordingly, the sources of error may interact with each other in different ways. Some of the sources of error described in the past, have a relatively stable and predictable character and can to some extent be tackled by anticipatory measures. For instance, the number of days required to estimate the intake of specific nutrients with a reasonable precision has been described extensively and this can a priori be incorporated in a protocol for planning research. Other sources of error are however more fluctuating and likely to vary much more across cultures and – within cultures – across subgroups of the population, for example lower social class subjects, younger age vs. older age, etc.

A number of validation studies have shown that misreporting is a major problem in dietary surveys of children and adolescents and so all the dietary data collected should be interpreted and evaluated with caution. In addition, each country uses a different set of food composition data. This can make comparisons between countries difficult and inaccurate. So, there are uncertainties over the true nutrient intakes of children and adolescents across Europe. There are also insufficient data on status to be able to draw any conclusions about the nutritional quality of the diets of European children and adolescents.

Obviously, dietary habits are influenced by age because physiological requirements as well as environmental influences are changing with age. Whereas the family environment strongly determines dietary intake and dietary habits in young children and thus risk of obesity, peer groups, food marketing and lifestyle are gaining increasing influence with age in older children and adolescents. Additionally, dietary intakes may change with time, for example due to dietary information or prevention campaigns. To examine potential influences of age on dietary intake and body weight, consumption data throughout all age groups in childhood and in adolescence are necessary. For different ages, some very specific problems have to be overcome in view of the changes in ability to report dietary habits, changes in cognitive skills and changing social contexts and behaviours. Recently, Huang *et al* pointed out that excluding implausible dietary reports is necessary for discerning dietary associations with BMI percentile (Huang *et al*, 2004). EI and meal, but not snack patterns could play a quantitatively greater role in weight regulation as children get older.

Regarding food and lifestyle habits, adolescents have particular food choices and meal habits compared to younger children and adults. Although all around Europe there are different cultural eating patterns, literature dealing with adolescents shows that globalisation is affecting adolescents in a similar way. One common finding is frequent skipping of meals, particularly breakfast (Hoglund *et al*, 1998). The main inadequate food consumption patterns are low consumption of fruits and vegetables, frequent snacking, with snack foods generally of a high fat/high sugar content (Alexy *et al*, 2002; Hoglund *et al*, 1998).

A 24-h recall method was selected by the EFCOSUM Group, as the best and most cost-effective method. To obtain the population distribution of usual intake, correction for within-subject variation is necessary. To this end repeated 24-h recalls are needed. A food classification system is needed to make food consumption data comparable at the food level. Foods can only be made comparable at the ‘raw edible’ ingredient level.

Dietary and nutrient intake data in the HELENA project will be obtained regarding these EFCOSUM proposals. The main objective is to develop, validate and establish innovative, standardised instruments and procedures for the assessment of dietary habits of adolescents across Europe to allow a comprehensive dietary characterisation by nutrient intakes, food consumption, meal patterns and nutritional knowledge and eating attitudes. Data from HELENA (food and nutrient intakes, body weight) might be a basis for developing complex approaches like Healthy Eating Indices.

8

General Discussion

As mentioned in the general introduction, the overall objective of this thesis is to study the dietary pattern of a population of Flemish adolescents, in both dimensions food safety and nutrition. Originally, the survey data have been collected within an international context of methodological issues concerning food safety. The Belgian part – GAStON-project – analysed the collected data in more depth which gave the opportunity to identify, measure and evaluate nutrition/food safety related problems in adolescents.

During decades, different international political commitments have urged for measuring, understanding and evaluating the health status through different health indicators in different settings of the population (World Health Organization, 1997; World Health Organization, 2001; World Health Organization, 2005). The objectives of this thesis could be seen as an attempt to achieve of some of the proposed actions. In this thesis a broad scope of nutritional issues and an illustration of food safety issues have been investigated. The reasons not to focus on one nutritional issue are merely:

(i) the thesis could be seen in the context of the above mentioned WHO-reports and actions which call for measuring, understanding and the dissemination of acquired information

(ii) the thesis could be identified with the first step of the Public Health Nutrition cycle and related to issues of health, not necessarily the absence of disease

(iii) the thesis could be seen as a collaboration of two parts of the three strategies proposed by the First Action Plan for Food and Nutrition Policy of the WHO-Europe (cfr. General Introduction)

(iv) in the Global Strategy for Food Safety report, the WHO stated that food safety is a public health priority (World Health Organization, 2002b). The EU has a similar report where they state that food safety is a key policy priority for the Commission and that risk analysis must form the foundation on which food safety policy is based (European Commission, 2000). As food safety is recognised as a public health priority by WHO and as it is for the EU a key policy priority, the food safety of acrylamide was discussed in this thesis.

The present work could also be situated in the context of two EU initiatives. These initiatives developed lists of public health nutrition monitoring indicators. In a first initiative, an EU

working group developed a list of indicators for monitoring public health nutrition in Europe (EU DG Health and Consumer Protection, 2003). The aim of that list was to define clearly indicators for nutrition and physical activity that should be monitored for nutrition-related health outcomes. This document emphasised that it should ideally be those indicators that are already being collected in the majority of Member States or those that can be added easily to current data collection systems in the Member States. The report also wanted to ensure comparability of the indicators among the different Member States. Therefore they suggested firstly that the classification of socio-demographic measures needs to be standardized across countries in future monitoring procedures along the guidelines of Kunst and co-workers (EU DG Health and Consumer Protection, 2001). Secondly dietary surveys need to include a detailed analysis of nutrients in the diet, including fatty acid composition, vitamin and mineral composition and the non-starch polysaccharide content. The indicators for food and nutrient intake were vegetables (exclusive potatoes and vegetable juice), fruit (exclusive fruit juice), fish, meat and meat products, saturated fatty acid content of the typical diet, poly-unsaturated fatty acids, mono-unsaturated fatty acids, non-starch polysaccharides, vitamins and minerals. This list has shown some similarity to a list of diet indicators for health monitoring in Europe proposed by another EU project, namely European Food Consumption Survey Method (EFCOSUM) (Steingrimsdottir *et al*, 2002). In the EFCOSUM-report the indicators are, in order of priority, vegetables, fruit, bread, fish, saturated fatty acids as energy percentage (E%), total fat (E%) and ethanol (g/day). Both reports also proposed indicators for nutritional status but these indicators were beyond the scope of the GAStON-project.
The available data collected in the GAStON-project were an ideal opportunity to describe all mentioned indicators in an adolescent population and as it is described in the EFCOSUM report, intake data are the pivotal element to assess both the covering of nutritional requirement and the exposure to food additives and contaminants.

As the next steps in the Public Health Nutrition cycle are to set goals, to define targets and to develop promotion programmes, the use of meal-based guidelines (chapter 3) and food-based dietary guidelines (chapter 4) are introduced. Food-based dietary guidelines (FBDG) are intended for use by the general public to provide nutrition education and dietary guidance in terms that are understandable to most consumers. FBDGs are a practical way to assist people to reach appropriate nutritional goals. Such guidelines take into account customary dietary patterns and indicate modifications needed to address particular concerns (Food and Agricultural Organization / World Health Organization, 1998).

In this thesis six main-analyses were performed on the basis of a detailed 7 days dietary study in an adolescent population. This chapter will discuss some methodological considerations, draw a general conclusion and an attempt on what the next steps could be in the public health nutrition cycle and research. First, the main findings of the studies will be briefly summarised.

Main findings of the thesis

In the first study, the aim was to estimate food consumption and nutrient intake in a random sample of Flemish adolescents aged 13 – 18 years. In this paper results were presented on the daily energy and macronutrient intake of teenagers and on their meal patterns; a comparison was made with other European studies and with the Belgian nutrient recommendations. The results of the study showed clearly that the pattern of macronutrient intake of Flemish adolescents differs from the current Belgian dietary recommendations. Especially, the mean intake of fat and mono/disaccharides is higher than recommended. Snacks were found to be an important source of mono/disaccharides and saturated fatty acids, while energy intake from breakfast was on average very low (chapter 2).

As it was known from the first study that the energy intake from breakfast was low, another study focused on breakfast consumption patterns – on nutrient and food item level – in Belgian adolescents. The results showed that in all adolescents, good quality breakfast consumers had a significantly higher intake of bread, fruit, vegetables, milk & milk products and fruit juice, while intake of soft drinks was significantly lower than in low quality breakfast consumers. On nutrient level, the results were not as uniform between the two sexes as on food item level. In boys, the energy contribution of polysaccharides was significantly higher in good quality breakfast consumers. The intake of all selected micronutrients was significantly higher in good quality breakfast consumers. In girls, the total energy intake, the proportional intake of proteins and polysaccharides was significantly higher in good quality breakfast consumers while the proportional contribution of total fat, monounsaturated and polyunsaturated fatty acids was significantly lower in these girls. The intake of the selected micronutrients is significantly higher in good quality breakfast consuming girls (chapter 3).

It is well-documented that saturated fatty acids have the capacity to raise the serum cholesterol (Keys & Parlin, 1966) and epidemiological studies provide evidence in support of the hypothesis that a higher dietary intake of saturated fat is associated with an increased risk of coronary disease but results from different studies are rather inconsistent (Hu *et al*, 1997; Kromhout *et al*, 1995). In the first study, the intake of saturated fatty acids in Flemish adolescents was identified as one of the major nutritional concerns and an important factor to tackle from public health point of view. Therefore existing data on habitual diets of adolescents have been explored to formulate food-based dietary guidelines aimed at reducing saturated fatty acid intake. The study showed that the most important contributors of saturated fatty acids on food group level were 'fats, oils & savoury sauces', 'meat & meat products', 'sugar, confectionary, sweet fillings & sauces', 'cheese', 'milk & milk products' and 'bread, rusk & breakfast rolls'. This analysis showed that the nutritional profile of Belgian adolescents could be potentially improved by decreasing the portion sizes of fresh meat (in boys), high-fat margarine, high-fat cheese and reducing intake of commercially prepared baked goods and processed foods, including fast foods (chapter 4).

Identifying nutrition-related health problems is the first step of the public health nutrition cycle and there the question arises if specific groups, especially socioeconomic groups are affected or not. It is well-known that differences in educational training underlie many health disparities. Inequalities in education are associated not only with diverging patterns in morbidity and mortality (Mackenbach *et al*, 2000) but also with the main determinants of health, such as the quality of the environment and health-related behaviours, such as nutrition (World Health Organization, 2002a). The results showed that in both, boys and girls, diet of general trained adolescents was more varied. More specifically in girls, the prevalence of overweight is higher when following vocational training or having a low parental education. In girls, the energy and micronutrient intake was higher in respondents with a general training and in those with a high parental education. Girls following a general training have significantly higher intake of fruit, vegetables, breakfast cereals, cheese and milk & milk products, while their intake is significantly lower for soft drinks. Girls with a high parental education have a higher intake of cake & biscuits and milk & milk products. In boys, small differences in micronutrient and food intake were found between different educational levels. The findings of this study showed that all adolescents – no distinction between educational levels – did not reach the national recommendations, but the situation was worst in lower social classes (Chapter 5).

The WHO stated that food safety is a public health priority and as scientists discovered large amounts of the chemical substance acrylamide – which might represent a potential threat to public health (European Commission, 2002a; Food and Agricultural Organization / World Health Organization, 2002) – in food, the need for a risk assessment of acrylamide intake in adolescents urged. The estimated median and 95th percentile dietary intake of acrylamide per person were respectively 0.51 and 1.09 µg/kg bw/d. Bread, despite its low acrylamide content, was relevant as a source of acrylamide exposure at the lower percentiles. At higher percentiles the contribution of French fries and crisps was more important. The risk of neurotoxicity seemed to be negligible and the relevance of current intake levels in terms of cancer risk remains a subject of debate (Chapter 6). In the current thesis only one chemical substance has been described out of a whole range of chemicals that may occur in the food chain. The author has chosen for acrylamide because it was at that time of high concern in the EU (European Commission, 2002a). The GAStON-data have been used for other exposure assessments as dioxins, this has been discussed in detail elsewhere (Vrijens *et al*, 2002). The current consumption data could be an ideal starting point for more exposure and risk assessments of chemical substances.

In the last study, some methodological issues of nutritional epidemiological research in adolescents had been investigated. This study was performed in collaboration with scientists of Spain and Germany and could be seen as an attempt to identify a probable uniform methodology to assess the dietary intake in adolescents in a European perspective. The Belgian part focussed on the effect of survey duration on underreporting and on nutrient intake. Based on the GAStON-project a decline in population mean energy intake was found over the seven days. Using clusters of days; the cluster of one recording day and the cluster of three recording days were not significantly different but they were both significantly different from the seven day cluster. No significant interaction was observed between the effect of time and BMI. The proportion of adolescents who were detected as under-reporters increased with more than ten percent from the first to the seventh day. Using clusters of days, the proportion of under-reporters doubled when one recording day was compared to seven recording days. The observed decline in reported population mean energy and energy yielding macronutrients over the seven day survey period is compatible with the increasing proportion of under-reporters, although theoretically these two phenomena can be quite independent from each other.

Methodological considerations

Since the separate studies that are reported in this thesis are the result of a larger epidemiological survey, some general methodological issues will be discussed.

The database used in this thesis dates from 1997. This may not be the most accurate reflection of the current pattern of nutrient and food intakes among adolescents but is the most representative survey up to date. This may be particularly true for certain food items which have changed in availability or in composition the last years (e.g., high-fat margarine, soft drinks) and could have an effect on the development of all kind of guidelines with a focus on food intake (Flynn & Kearney, 1999).

The general questionnaire that has been used in this thesis is restricted and has collected general data about the adolescents' place of residence (rural versus urban), the number of brothers and/or sisters, the educational level of both parents, the country of birth of both parents (born in Belgium or abroad) and the family status (parents living together or apart). This questionnaire has not been validated and the quality could be questioned. However, the author is convinced that the adolescents could answer the questions about themselves with a high accuracy. On the other hand a Norwegian study found that the strength of agreements between adolescents' and parents' reports of parental education was rather weak (Lien *et al*, 2001a). This could be a limitation of this thesis.

It is acknowledged that dietary intake cannot be estimated without error and probably never will be (Beaton, 1994), a greater understanding of the nature and magnitude of the errors will lead to more scientific and sensible interpretation of the results.

Study population and number of days needed

The GAStON-project was part of a multi-centre epidemiological study. This international study was an observational, cross-sectional study. Another character of the study design is concerned with observing the distribution of health states in populations. In epidemiological literature it is described that it is important to specify very precisely what the population is and where it comes from. This will make clear to which population the conclusions of the study refer (Cole, 1997). In cross-sectional studies, the sample is likely to be obtained from the target population by selection based on criteria other than time. Randomization has been suggested to ensure that no biases, conscious or unconscious, influence the choice of the subjects. The whole sampling procedure has been described in the different chapters. A multistage cluster sampling has been used. A random sampling at the individual level would have been methodologically better, although the author does not have arguments to assume that the procedure used in this study would introduce any measurable selection bias. A possible limitation of the thesis is that a multistage cluster sampling design has been used but the analyses were done assuming that the participants were individually randomised and not clustered. An analytical approach that allows the simultaneous examination of the effects of group-level and individual-level on individual-level outcomes, namely multilevel analysis or hierarchical modelling would be more appropriate to analyse the results. Multilevel analysis allows the simultaneous examination of the effects of group-level and individual-level predictors, it accounts for the nonindependence of observations within groups, it takes into account that groups or contexts are not treated as unrelated, but are seen as coming from a larger population of groups and both interindividual and intergroup variation can be examined (Diez-Roux, 2000). Multilevel analysis is characterised by the use of complex models and can only be used when different side constraints are accomplished. Multilevel analysis can be completed when (a) relatively large data sets are available, (b) enough power to detect between-school variability is foreseen, given the number of schools and the average number of persons per school (c) the groups that are investigated are not arbitrary or convenient groupings of individuals, but rather groups that are hypothesized to be meaningful in explaining the outcome. In addition, the uses of very crude and indirect proxies for school variables are disadvantages when using multilevel analysis (Diez-Roux, 2000). The use of multilevel modelling in this thesis would be difficult and create some extra methodological considerations because of lack of power (i.e. small sample size, restricted number of schools) and there is a lack of information about the school characteristics. Some studies have used multilevel modelling to analyse the impact of school (class) on the dietary behaviour of adolescents. A Danish study found that the school has little to no effect when the dietary pattern was considered. The study concluded that family circumstances comprised the strongest influence on dietary habits of adolescents (Johansen *et al*, 2006). This finding is in accordance with a Belgian study where it was found that the school has a small or no impact on healthy and unhealthy nutrition behaviour of adolescents (Maes & Lievens, 2003). This could be explained by what students bring to the schools is at least as important as the possible impact of the school itself and that the socio-economic background of the students is possibly more important for there health behaviour (Karvonen & Rimpela, 1996; Maes & Lievens, 2003). In spite of the preconditions (e.g., sample size and school information) using multilevel modelling formulated by Diez-Roux (2000), the author executed a multilevel analysis (in SPSS) for the energy intake and found that the cluster school had no effect on the difference between boys and girls. This means that the difference between schools is smaller than the difference between individuals. Similar results were found when social variables (education type of adolescent and educational level achieved by parents) were included in the multilevel analyses. The results of these multilevel analyses confirm the results described in the different chapters. In addition, Diez-Roux stated that many hypotheses regarding the social determinants of disease can and should be tested with individual-level data and supposing that diet is an indicator of disease the author beliefs that a multilevel analysis in the current circumstances (small sample size and no school information) would probably not have a major influence on the overall results of the thesis (Diez-Roux, 2000).

A total sample of 341 adolescents was achieved after excluding non-responders and finishing the quality control of the food record procedure. In general, non-response is a cause that the final sample size is smaller than originally planned. One could include a scaling-up factor in the calculation of sample size to cover this (Cole, 1997). However, it is not known how big this factor has to be. The effect of the non-responders and non-included (excluded due to incomplete diaries) subjects has been investigated. In both boys and girls, the loss of subjects (due to non-participation or incomplete diary) was significantly higher in students from vocational education as compared with students from general education. A similar phenomenon was observed for age with higher proportional drop-out in older age-groups as compared with younger age-groups. To control the validity of the sample size, anthropometrical data from the study population are compared with the data from a random sub-sample of the non-included subjects (excluded due to incomplete diaries). Weight has not been found significantly different between those groups. The proportion of adolescents who suffer from overweight does not differ between the included and the non-included subjects. According to the EU-EFCOSUM working group, a minimum sample size of 2000 adults seems to be reasonable in order to identify trends of food and nutrient intakes (Volatier *et al*, 2002). Compared to this guideline a sample size of 341 adolescents could be rather small and could be a methodological disadvantage of the present study. Especially, for analyses where dietary habits are related to social differences, particularly, the limited number of boys in vocational education causes a lack of power in the analyses. The originally selected sample size contained only 56 boys who follow a vocational education. This is explained by the study design where schools with vocational education were less well represented. However, it could be said that the sample size needed depends on the survey methodology; it is lower for surveys based on records (Volatier *et al*, 2002). From a statistical point of view the number of repetitions of recording days and the number of individuals should be chosen in such a manner that the confidence intervals for the percentiles are as small as possible. Since the length of such an interval decreases if the number of individuals increases whereas the length is not systematically influenced by a change of number of repetitions of recording days, it is described that the best choice of the number of replicates is two by simultaneously maximising the sample size (Hoffmann *et al*, 2002; Willett, 1998). However, if the purpose of the study requires estimating the distribution of individual intakes within the group, it is necessary to collect more than one record or recall per individual in the study population (Guenther *et al*, 1997). Theoretically, studies suggest that the minimum of days of intake required for gross characterisation of usual intake of energy and macronutrients ranges from three to ten days

(Basiotis *et al*, 1987; Nelson *et al*, 1989). In the case of food records, it could be more cost effective to train fewer people in record keeping and increase the number of days per individual (Willett, 1998). Different studies recommended using non-consecutive days when multiple records were used (Hartman *et al*, 1990; Hoffmann *et al*, 2002; Tarasuk & Beaton, 1992). However, if the days are non-consecutive, the logistics of data collection for several days may become a limitation. As it was decided that the usual intake of individuals has to be calculated the research team has chosen to collect seven days, which is in general accepted as a representation of the current 'usual' intake (Nelson & Bingham, 1996), combined with a more limited sample size. More ideal is to spread the seven days out over the seasons. Theoretically, it is assumed that the sampling period is not atypical (Cole, 1997). A methodological shortcoming of the present thesis is that the sampling period was limited to three months (during spring), therefore it is not possible to describe seasonal effects. The effect of this limitation is discussed in each chapter separately.

Food Consumption Databases and Conversion system

For the identification of foods our own food coding system has been used and is mainly based on the Dutch food composition database, NEVO (NEVO, 1993). Two kinds of food composition databases were used for the conversion of foods into nutrients, namely the Dutch and Belgian database (NEVO, 1993; NUBEL, 1992). The fibre intake has been calculated based on the Dutch database version 1996 (NEVO, 1996). Systematic and random errors in food composition databases could bias the nutrient intakes and make them incomparable at an international level. These errors may lead to wrong measurements and conclusions concerning the identification of nutrition related problems (Greenfield & Southgate, 1992). However, it is described that these databases are of great value in epidemiological research, but knowledge of how they are constructed and their limitations is necessary to make intelligent use of them. Moreover, in general it is better to use local food composition tables (West & van Staveren, 1997). However, a common food classification system would be better to make food consumption data at food level internationally comparable, a similar system should be developed at nutrient level (Ireland *et al*, 2002).

Dishes were broken down into their constituent ingredients under the condition that all the ingredients were known and described. Sometimes dishes were not broken down into their ingredients, because the composition was not known. Decisions regarding the grouping of foods and the disaggregating of dishes were based on the judgement of the investigators. The storage of the data in this thesis does not allow us to see what the effect is of classifying in different ways. On one hand this methodology does not allow one to ascertain the importance of dishes as a source of nutrient but on the other hand it has been reported that the disaggregation of dishes gives a more precise picture of the dietary contributions of various food groups (Krebs-Smith *et al*, 1990).

Dietary assessment method

The estimated technique was chosen in preference to the weighed technique because of the high respondent burden, high financial impact and time consuming characteristic of the latter. Knowing that the estimation of portion size, rather than direct weighing, introduces imprecision in the diet record as well (Bingham, 1991). However, in a comparison study, researchers assessed the validity of the estimated food diary by comparing recorded and observed food intakes for 121 subjects (71 men and 50 women) aged 15 to 65 years. They concluded that the validity is very satisfactory on the group level and is probably acceptable on the individual level (Karvetti & Knuts, 1992). It is also stated that estimated records are less accurate than weighed records of individuals' diets, but they have the same order of accuracy when ranking subjects into thirds or fifths (Bingham *et al*, 1988). However, Nettleton and co-workers (1980) found that the validity of the estimated record against the weighed record does not differ very much, they found differences of 2 – 5 percent depending on the type of nutrient and population studied (Nettleton *et al*, 1980). To increase the validity of the food record, the research team provided an instruction session at the beginning of the survey, as it is known that training in portion size estimation can improve the accuracy of dietary self-reporting in adults (Livingstone *et al*, 2004).

Misreporting

A major limitation of food records are the tendency for people to eat differently when recording their intakes, especially during longer periods of consecutive days, as in this survey (Hartman *et al*, 1990; Thompson & Byers, 1994). Livingstone and co-workers (2004) stated that ranking of

adolescents based on only seven days of records will be grossly inaccurate, even if splitting the required recording period into discrete time periods (Livingstone *et al*, 2004). This statement is based on different validation studies, which express doubts about the use of a seven day diet record as the method of choice for assessing total energy and nutrient intake in adolescents. The results of different studies (Bandini *et al*, 1990; Bandini *et al*, 1997; Bratteby *et al*, 1998; Livingstone *et al*, 1992), indicate that the energy intake of adolescents is underestimated by approximately 20 % by the diet record method. The most common reason of the observed bias in self reported dietary intake methods is that the procedure is regarded as a burden, which probably promotes underreporting of dietary intake (Goldberg *et al*, 1991). The issue of misreporting is widely accepted and is a major problem in dietary surveys. To avoid this problem the use of the doubly labelled water technique could be introduced as a routine for detecting bias in energy intake, unfortunately the cost and technical complexity of this technique exclude the use on regular bases. However, an alternative is the evaluation of the reported energy intake against presumed energy requirements, expressed as physical activity levels (Goldberg *et al*, 1991). Throughout the different chapters attention has been paid on the issue of misreporting and will not be discussed further. In the meantime, the most appropriate action to take when evaluating nutrient intake data is to assume that the reported intakes are minimum true intakes, while accepting that for some nutrients an over-estimation will be made (Livingstone *et al*, 2004).
As Livingstone and co-workers (2004) argued that a seven day food record is grossly inaccurate, other studies argue that a potential error of short survey duration is the misclassification of individuals into high and low intakes of food items and nutrients (Freudenheim *et al*, 1987; Lambe & Kearney, 1999). A recent study calculated that to assess actual food intake of individuals with a certain level of confidence a high number of days is needed (Palaniappan *et al*, 2003). Another plea for long survey durations is in the context of food safety, where it is stated that the length of time over which dietary samples are to be collected is several consecutive days at multiple intervals of months, seasons and years (Kroes *et al*, 2002).

Until these issues are better understood, it is not clear how the possible impact of the mentioned methodological considerations may have affected the results of this thesis. Fortunately, it is stated that a mean of 1-d intakes by individuals in a group can be an unbiased estimate of the group's usual mean intake (Guenther *et al*, 1997). The findings of chapter 7 and the literature, a decrease in energy intake when survey duration increases, suppose that it would have been better to estimate the group's usual mean intake in the different chapters of the thesis based on the first two record days (Hoffmann *et al*, 2002; Livingstone *et al*, 2004). Moreover, these two food record days could be used to describe the habitual dietary intake distribution of the population (Hoffmann *et al*, 2002). To illustrate these findings, the author completed some extra calculations and found that the energy intake and fibre intake based on two food record days was higher than based on a seven day intake but the differences were rather small. However, in the current context, one could assume that the collected data reflects a reliable dietary pattern at population level. In the meantime, one should make intelligent use of these data and be cautious when evaluating the data.

Exposure Assessment

In the context of food safety research an exposure assessment was completed. The most important purpose of exposure assessment is to assess whether exposure to a chemical (naturally occurring, intentionally added or unintentionally added substance) is below acceptable or tolerable levels for the ultimate protection of the consumer. Several methods exist to estimate the intake of a chemical from a food. The selection of method is determined by the purpose of the assessment, the nature of the chemical and the availability of resources (Kroes *et al*, 2002; Petersen & Barraj, 1996). Different approaches have been described to combine food consumption with chemical concentration data (Kroes *et al*, 2002; Lambe, 2002). The point estimate approach is a single 'best guess' estimate of each variable within a model to determine the model's outcome(s) (Vose, 2000). Typically, a fixed value for food consumption is multiplied by a fixed value for chemical concentration relevant to that food. The chemical intake from all foods is then summed to estimate total dietary exposure (Kroes *et al*, 2002; Lambe, 2002). A common assumption inherent to the point estimate approach, is that all individuals consume the specified food(s) at the same level, that the food chemical is always present in the food(s) and that it is always present at an average or high level (Kroes *et al*, 2002; Lambe, 2002). The approach ignores the existence of variability in food consumption and chemical concentration levels and therefore, does not provide an insight into the range of possible exposures that may occur within a population (Gilsenan, 2003). When high percentile values are used to represent food consumption and/or chemical concentration, summing the intakes from multiple sources may lead to very conservative and often implausible estimates of intake. These are worst case or upper-bound estimates (Cullen & Frey, 1999; Petersen, 2000).

This deterministic approach is relatively simple and inexpensive but it has a number of shortcomings. A main disadvantage of the deterministic approach is that uncertainty and variability associated with the exposure variables are not taken into account. Secondly there is no consensus about the definition of high-level consumers, which makes comparisons of assessment results very difficult (Benford & Tennant, 1997). Shortcomings of deterministic approach are widely discussed by Cullen & Frey (1999), Petersen (2000), Kroes *et al*. (2002) and Lambe (2002). Probabilistic analyses make results from exposure assessments more informative by giving some perspective of the uncertainty behind point estimates (Thompson *et al*, 1992). Some major advantages of the probabilistic approach for exposure assessments as discussed by different authors are (i) it permits to consider the whole distribution of exposure, from minimum to maximum, with all modes and percentiles, and presents a more refined and more realistic estimate of exposure; (ii) it provides a more comprehensive characterization of variability (e.g., natural variation) in risk estimates, thereby providing more meaningful information on likely exposures that may occur within a population; (iii) provides a quantitative measure of uncertainty in estimates of exposure, which may support statements regarding confidence in exposure estimates and (iv) avoids disputes over the best point estimate to use (e.g., mean or upper percentile) (Kroes *et al*, 2002; Lambe, 2002). Several authors gave a more extensive list of the benefits of probabilistic methods (Ferrier *et al*, 2002; Finley & Paustenbach, 1994; International Life Science Institute, 1998; United States Environmental Protection Agency, 2001). However, the use of a probabilistic analysis is more complex, more time consuming and more resource intensive than traditional deterministic methods. Situations in which a probabilistic analysis may not confer any benefit are (i) when a screening level deterministic calculation indicates that exposures/risks are negligible, (ii) where there is little variability and uncertainty in the model inputs and (iii) when the probabilities are so uncertain, that detailed probabilistic judgements are impossible (Cullen & Frey, 1999; United States Environmental Protection Agency, 1997).

In the context of this thesis the author believes that the use of a probabilistic model was the best choice, keeping in mind the different advantages and shortcomings.

General conclusion

As it is described, before the purpose of this thesis was to identify various nutrition/food safety related problems in adolescents. Therefore the thesis could be situated in the first step of the PHN cycle. This survey contributes to the existing knowledge in various ways. Firstly, the used methodology has been questioned widely and it was found that one should make intelligent use of these data and be cautious when evaluating the data. Secondly, this study showed that the pattern of macronutrient intake of Flemish adolescents differs from the current Belgian dietary recommendations and the energy consumed during breakfast was too low. In the broad context of a search for elements that may be helpful for developing strategies to implement the translation of nutrient dietary guidelines into food and meal based dietary guidelines, it was found that the nutritional profile of Belgian adolescents could be substantially improved by decreasing the portion sizes of fresh meat (in boys), high-fat margarine, high-fat cheese, choosing vegetable oils and reducing intake of commercially prepared baked goods, snack foods, and processed foods, including fast foods. Another option would be to choose lean alternatives, if available. While on meal level it was found that the nutritional profile could be improved by the consumption of a healthy breakfast in a family setting on a daily basis consisting of a variety of foods, namely whole grains products, fruit and (semi-) skimmed milk products or an alternative source of calcium. Meanwhile, from a food safety point of view, based on the acrylamide issue illustrated in this thesis, people should be advised to avoid excessive frying or baking, especially with regard to potato products.

Although the sample is small, these findings demonstrate trends which highlight the need for continued health promotion efforts to improve the diet of adolescents in all social classes in Belgium, but particularly in lower social groups. However, this thesis gives only the opportunity to identify nutrition related problems and is limited in the sense that the available data only gives a small basis of defining evidence-based guidelines – as is defined by the PHN cycle – that can be used in the future.

What is the next step?

The next step in the Public Health Nutrition cycle is to set goals, to define objectives for these goals and to create quantitative targets. The strength of this cross-sectional epidemiological study is that it could generate some recommendations how our federal or regional governments could help to realize the next steps of the PHN-cycle. Actions on different levels can be undertaken:

(i) starting and supporting **health promotion campaigns**. In Belgium and Flanders there exist already nutrient and food recommendations but these could be seen as the goals to enhance the diet quality of the overall population (Nationale Raad voor de Voeding, 1996; Vlaams Instituut voor Gezondheidspromotie, 2003). Based on the findings of this thesis one could specify adolescent health promotion campaigns aimed at: e.g.,

   i. increasing the intake of fruit and vegetables
   ii. reducing the intake of saturated fatty acids
   iii. reducing the 'healthy eating' gab between different social classes

(ii) launching a **nutritional monitoring and surveillance system**. As dietary habits change continuously over time in adolescents but also in other strata of the population, it is important to be aware not only of the current dietary patterns but also of any subsequent change in the future. Therefore there is a need of continuous monitoring surveys which provide updated information about the nutrition related problems and dietary patterns and which enable us to evaluate the proposed health promotion campaigns (cfr. supra). Different international accepted documents support this proposal; e.g., as it is described in the First Action Plan for Nutrition of the WHO, *the development and funding of monitoring surveys and cost-effective tools has to be stimulated* (World Health Organization, 2001). A first onset of a nutritional monitoring survey has been taken by the federal government, which supported financially the National Belgian Food Consumption Survey. A reflexive system of nutritional monitoring and surveillance with a focus on children and young people could also contribute to the areas of action of the EU – 'Green Paper' (European Commission, 2005).

(iii) **research promotion**. The some specific findings of the GAStON-project generated new studies. These projects are next steps in further research but to finish the Public

Health Nutrition cycle, there is a need for more. Finishing the next steps of the cycle are issues where we have to focus on for the next years. New research has to be generated to complete the whole process of Public Health Nutrition cycle and it would be disappointing when one could only gather baseline information without proceeding with the steps on the road to full commitment to the concept of PHN in this subgroup of the general population.

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SUMMARY

Adolescence is a particularly unique period in life as it is characterized by intense physical, psychosocial and cognitive development. From nutritional point of view, this transition period from childhood to adulthood deserves special attention in view of the remarkable physical changes of the body. Increased nutritional needs relate predominantly to the fact that adolescents gain up to 50% of their adult weight, more than 20% of their adult height and 50% of their adult skeletal mass during this period. During adolescence, nutritional problems originating earlier in life can potentially be corrected, in addition to addressing current ones. It is also a period to shape and consolidate healthy eating and lifestyle behaviours, thereby preventing or postponing the onset of nutrition-related chronic diseases in adulthood. In the context of the "First Action Plan for Food and Nutrition Policy of the World Health Organisation - European Region" attention has been paid on the issue of food safety. This thesis aimed to identify nutritional and food safety issues that contribute to adolescents' health.

For the analyses, data of the 'Ghent Adolescent Study On Nutrition' were used. This study includes data on dietary pattern of Flemish adolescents, between 13 and 18 years old. The study was part of an international collaborative project, looking at methodological aspects of dietary assessment in the context of food safety monitoring.

First, some specific nutritional issues for the Flemish subpopulation are studied. Chapter 2 describes the estimated energy intake, macronutrient intake and meal pattern of adolescents. The results showed clearly that the pattern of macronutrient intake of Flemish adolescents differs from the current Belgian dietary recommendations. Especially, the mean intake of fat and mono/disaccharides is higher than recommended. Snacks were found to be an important source of mono/disaccharides and saturated fatty acids, while energy intake from breakfast was on average very low. In chapter 3, the position of breakfast in the overall diet has been investigated in more detail and more precisely the importance of breakfast in relation to the global dietary pattern. The results showed that in all adolescents, good quality breakfast consumers had a significantly

higher daily intake of bread, fruit, vegetables, milk & milk products and fruit juice, while intake of soft drinks was significantly lower than in low quality breakfast consumers. On nutrient level, the results were not as uniform between the two sexes as on food item level. Overall, good quality breakfast consumers had a significantly higher intake of 'healthy' food products. In chapter 4 a search for the main food sources of total fat and saturated fatty acids has been conducted with the purpose to develop food-based dietary guidelines for adolescents. The results showed that the most important contributors of saturated fatty acids on food group level were 'fats, oils & savoury sauces', 'meat & meat products', 'sugar, confectionary, sweet fillings & sauces', 'cheese', 'milk & milk products' and 'bread, rusk & breakfast rolls'. This analysis showed that the nutritional profile of Belgian adolescents could be potentially improved by decreasing the portion sizes of fresh meat (in boys), high-fat margarine, high-fat cheese and reducing intake of commercially prepared baked goods and processed foods, including fast foods.

Secondly, an overview of social inequalities at nutrient and food level between different socioeconomic groups based on the educational training of the adolescent and the educational level of the parents is given. The results showed that in both boys and girls, diet of general trained adolescents was more varied. In girls, the energy and micronutrient intake was higher in respondents with a general training and in those with a high parental education. Girls following a general training have significantly higher intake of 'fruit', 'vegetables', 'breakfast cereals', 'cheese' and 'milk & milk products', while their intake is significantly lower for 'soft drinks'. Girls with a high parental educational level have a higher intake of 'cake & biscuits' and 'milk & milk products'. In boys, small differences in micronutrient and food intake were found between different educational levels. The findings of this study showed that all adolescents – no distinction between educational levels – did not reach the national recommendations, but the situation was worst in lower social classes.

Thirdly, an illustration of one of the many food safety aspects that can occur in the dietary pattern of adolescents is shown. The consumption data are linked to contamination data (e.g., acrylamide) to estimate the long-term intake of contaminants. The estimated median and 95th percentile dietary intake of acrylamide per person were respectively 0.51 and 1.09 µg/kg bw/d. Bread, despite its low acrylamide content, was relevant as a source of acrylamide exposure at the lower percentiles. At higher percentiles the contribution of French fries and crisps was more important.

Fourthly, in chapters 2 and 7 some methodological issues about the accurate assessment of food and nutrient intakes in adolescents are described. The analyses focussed on the effect of survey duration on underreporting and on nutrient intake. A decline in population mean energy intake was found over the seven days. Using clusters of days; the cluster of one recording day and the cluster of three recording days were not significantly different but they were both significantly different from the seven day cluster. The proportion of adolescents who were detected as under-reporters increased with more than ten percent from the first to the seventh day.

Finally, this cross-sectional epidemiological study gave the opportunity to generate some recommendations that our federal or regional governments could help to realize the next steps of the Public Health Nutrition-cycle. Actions on different levels can be undertaken:

(i) starting and supporting health promotion campaigns

(ii) launching a nutritional monitoring and surveillance system

(iii) research promotion

SAMENVATTING

Adolescentie is in de levenscyclus van de mens een vrij unieke periode. Het is een fase die gekenmerkt wordt door fysische, psychosociale en cognitieve ontwikkeling. De overgang in de ontwikkeling tussen kind en volwassene, is een groeifase met een verhoogde behoefte aan nutriënten. Deze verhoogde eisen zijn waar te nemen in een gewichtstoename (tot 50% van het volwassen gewicht), in groeischeuten (tot 20% van de volwassen lengte) en in een toenemende sterkte van het beendergestel van adolescenten. Adolescentie wordt gekenmerkt als de periode in de levenscyclus waar het vroegere en huidige voedingsgedrag kan aangepast worden. Het bijsturen van voedings- en leefgewoonten is dan ook een belangrijk aangrijpingspunt in de preventie van voedingsgerelateerde chronische aandoeningen. In kader van het 'First Action Plan for Food and Nutrition Policy of the World Health Organization – European Region' werd ook aandacht besteed aan het luik voedselveiligheid bij adolescenten. In dit proefschrift wordt de betekenis van voeding – op nutritioneel en voedselveiligheid vlak – voor de gezondheid van adolescenten onderzocht.

Voor de analyses is gebruik gemaakt van de gegevens van de 'Ghent Adolescent Study On Nutrition'. Deze dataset bevat gegevens over voedingsgewoonten van Vlaamse adolescenten, tussen 13 en 18 jaar. Het vernoemde project maakte deel uit van een internationaal project met een focus voor methodologische aspecten van voedselveiligheid onderzoek.

In dit proefschrift werden een aantal onderdelen van de kwaliteit van het voedingspatroon van Vlaamse adolescenten meer in detail geanalyseerd. Hoofdstuk 2 beschrijft de geschatte inname van energie, macronutriënten en het maaltijdpatroon van de doelgroep. De resultaten toonden aan dat het huidige patroon van macronutriënteninname sterk afwijkt van het gewenste profiel, weergegeven door de Belgische aanbevelingen. Het valt voornamelijk op dat er voor de inname van vet en enkelvoudige suikers een belangrijk verschil bestaat tussen de realiteit en de aanbevelingen. Tussendoortjes worden gekenmerkt als belangrijkste moment van inname van enkelvoudige suikers en verzadigde vetzuren. Anderzijds is de energie inname gedurende het ontbijt behoorlijk laag. In hoofdstuk 3 werd de positie van het ontbijt in het globale voedingspatroon bestudeerd, meer specifiek naar het belang van het ontbijt in relatie tot de kwaliteit van het voedingspatroon. Er werd aangetoond dat enerzijds ‘goede ontbijters’ een significant hogere inname hebben van brood, fruit, groenten, melk & melkproducten en fruitsap, terwijl anderzijds hun inname van frisdranken significant lager is dan in ‘slechte ontbijters’. De resultaten op nutriëntenniveau waren niet zo éénvormig als deze voor voedingsmiddelen. Globaal kon men vaststellen dat ‘goede ontbijters’ een hogere inname van ‘gezonde’ voedingsmiddelen vertoonden. In hoofdstuk 4 werden de belangrijkste voedingsmiddelenbronnen van totaal vet en verzadigde vetzuren bestudeerd, welke op hun beurt de start waren voor de ontwikkeling van voedingsmiddelenaanbevelingen. De resultaten toonden aan dat de belangrijkste bronnen van verzadigde vetzuren, op voedingsmiddelengroepenniveau, ‘vetten, oliën & hartige sauzen’, ‘vlees & vleeswaren’, ‘suiker, snoep, zoet beleg & zoete sauzen’, ‘kaas’, ‘melk & melkproducten’ en ‘brood, beschuit & koffiekoeken’ waren. De analyses in dit hoofdstuk toonden aan dat het voedingspatroon van de adolescenten kan bevorderd worden door het consumeren van kleinere porties vlees (voornamelijk bij jongens), margarine met hoog vetgehalte, kaas met hoog vetgehalte en door de consumptie van industrieel bereide producten, inclusief ‘snelle voeding’ te beperken.

In een tweede luik werd aandacht besteed aan de sociale ongelijkheid in het voedingspatroon van adolescenten. Sociale ongelijkheid was gebaseerd op de opleiding van de adolescenten en de opleiding van de ouders. De resultaten toonden aan dat het voedingspatroon van jongeren die een humaniora opleiding volgen meer gevarieerd is. Bij de meisjes werd vastgesteld dat de energie- en micronutriënteninname hoger is bij meisjes die een humaniora opleiding volgen en bij de meisjes waarvan beide ouders hebben verder gestudeerd. Meisjes met een humaniora opleiding hebben een significant hogere inname van fruit, groenten, ontbijtgranen, kaas en melk & melkproducten, terwijl hun inname van frisdrank significant lager is dan meisjes die een beroepsopleiding volgen. Meisjes waarvan beiden ouders verder gestudeerd hebben, consumeren meer ‘koek & gebak’ en ‘melk & melkproducten’. Bij de jongens werden verschillen vastgesteld in de inname van micronutriënten en voedingsmiddelen. De resultaten van dit tweede luik toonden aan dat het voedingspatroon van alle adolescenten, overheen de sociale klassen, niet voldoet aan de aanbevelingen, maar de situatie is het minst gunstig in de sociaal lagere klassen.

In een derde luik werd blootstellingsanalyse uitgevoerd. In deze analyse werd de inname van de chemische substantie acrylamide bestudeerd. De volledige range van alle chemische stoffen die kunnen voorkomen in het voedingspatroon werd niet bestudeerd en men kan de analyse van de inname van acrylamide aanzien als een illustratie van voedselveiligheidanalyse. Voor de analyses werd gebruik gemaakt van probabilistische technieken. De geschatte mediaan en 95ste percentiel inname van acrylamide via de voeding per persoon waren respectievelijk 0.51 en 1.09 µg/kg lichaamsgewicht/d. Brood, ondanks de lage contaminatiewaarden, was een belangrijke bron van acrylamide-inname bij de lagere percentielen. Frieten en chips waren de belangrijkste bronnen bij hogere percentielen.

In een vierde luik werden enkele methodologische aspecten van voedingsonderzoek bij adolescenten naderbij onderzocht. De analyses behandelden voornamelijk het effect van de onderzoekstermijn op onderrapportering en op de inname van enkele nutriënten. Een daling van de energie inname over zeven dagen werd vastgesteld op populatieniveau. Wanneer men gebruik maakte van clusters van dagen stelde men vast dat de cluster van één dag en de cluster van drie dagen niet significant verschillend waren in energie-inname maar beiden waren significant verschillend in energie inname van de cluster van zeven dagen. Het aandeel van de adolescenten dat gedetecteerd werd als onderrapporteerder steeg met meer dan 10% wanneer men de eerste dag vergeleek met de zevende dag.

Tenslotte kon men aan de hand van de bekomen resultaten van deze cross-sectionele epidemiologische studie een aantal aanbevelingen naar voor schuiven die zowel het Federaal als het Gewestelijk beleid kan helpen om de 'Public Health Nutrition-cyclus' te vervolledigen. Verschillende acties kunnen ondernomen worden:

(i) het starten en ondersteunen van gezondheidspromotie campagnes

(ii) het lanceren van een systeem dat toelaat om op continue basis voedingsgewoontes van de totale bevolking te bestuderen

(iii) de promotie van onderzoek, meer specifiek voedingsgerelateerd onderzoek

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Een proefschrift dat handelt over voeding en dat door een lid van de Vakgroep Maatschappelijke Gezondheidkunde geschreven wordt, kan niet losgekoppeld worden van onderstaande formule. Wiskundig stelt deze formule niet zoveel voor maar het is het EQ dat eventjes telt. Voor mij betekent voeding het product van het werk van vele mensen. Het product wordt overschouwd door het 'dagelijks bestuur' van Stefaan en Annemie. De verschillende delen van het product bestaan uit een deel dat voor uitstekende data zorgt en voor een kritisch oog naar interpretatie, namelijk Mieke en Mia. Zonder hun inbreng zou het overige deel van het product, het 'jong geweld' (Ilse (dank om de verkeerde komma's en punten uit mijn teksten te halen), Inge, Tineke, Carine, Maaike (dank om mijn taalpurist te zijn), Isabelle en Christophe) er niet in slagen om een wetenschappelijke output te creëren. Dit geheel wordt uiteraard nog overgoten met een sausje van kritisch inzicht van Prof. Dr. J. Willems. Ik wil hen daarvoor danken.

$$\forall Voeding \in Gezondheid : \prod_{a=1}^{PDH} \left[Mi \,\&\, Mi \cup \frac{I_l * I_n * T * C_a}{M_a * I_s * C_h} \right]^{PW}$$

waarbij: *PDH* = Prof. Dr. S. De Henauw; *a* = Annemie; *Mi & Mi* = Mieke & Mia; I_l = Ilse; I_n = Inge; T = Tineke; C_a = Carine; M_a = Maaike; I_s = Isabelle; C_h = Christophe en PW = Prof. Dr. J. Willems.

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Christophe Matthys
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About the author

Christophe Matthys was born in Ghent, Belgium on March 5, 1975. In 1993, he passed secondary school, at the ‘Sint-Amandus Instituut’ in Ghent and started the same year the study ‘Bio-Engineer in Agricultural Science’ or as it is now called ‘Master of Bioscience Engineering: Agricultural Sciences’ at the Faculty of Agricultural and Applied Biological Sciences (now called the Faculty of Bioscience Engineering), Ghent University.

In 1998 he obtained his MSc degree. During the last year, he conducted three months of fieldwork in the Luapula Valley in the Northern part of Zambia, for his dissertation entitled ‘Analysis of the food intake in Mwense and Kawambwa Districts, Zambia’. This research project was part of a broader ongoing study ‘Improving Household Food Security and Nutrition in the Luapula Valley, Zambia’ coordinated by the UN Food and Agricultural Organization (FAO), in collaboration with the Government of Zambia with funding by the Belgian Survival Fund.

Since September 1998 he is a member of the scientific staff of the Department of Public Health of the Faculty of Medicine and Health Science, Ghent University. His first task was to analyse the original data of the GAStON-project. After three months he got involved in the preparation, coordination and fieldwork of the Survey in Europe on Nutrition and the Elderly: a Concerted Action (SENECA), which he combined with the development of a fat and fibre indicator based on household budgets surveys.

Since September 1999 he worked as a nutritional epidemiologist at the Department, mainly on different nutritional issues in different subgroups (e.g., pre-school children, young women, elderly) of the Belgian population. In the meantime he gained a growing interest in methodological issues about nutritional epidemiology and food safety research. In this period he completed courses in statistics (Linear regression) and epidemiology (11th European Postgraduate Summer Course in Public Health Nutritional Epidemiology).

Since March 2001 a new topic of interest has been found in the ‘Social stratification in the purchase and consumption of food items and its consequences for public health’ project. In the context of this project he followed in June 2002 the 1st International Course in Social Epidemiology, Socioeconomic Differentials in Health, organised by the European Education Programme on Epidemiology.

In October 2002 he started his PhD-project and combined the above mentioned research activities with the writing of this thesis. By the end of 2002 he completed his doctoral training programme in medical science. In March 2004, he had the opportunity to follow the 10th edition of the European Nutrition Leadership Programme (ENLP), and is since then a member of the ENLP Alumni Association. In June 2005, he participated in the EU Basics in Public Health Nutrition Summer Course.

Since August 2005 he is part of the assisting academic staff of the Department of Public Health.

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